

MASTER PLAN

Intelligent Vehicle-Highway Systems

Denver Metro Area

Project IVH-MP 9108(1)

for the
**COLORADO DEPARTMENT
OF TRANSPORTATION**

C-STAR 

February 1994

**CENTENNIAL ENGINEERING INC.
CASTLE ROCK CONSULTANTS
BALLOFFET AND ASSOCIATES INC.**



IVHS Study for the Denver Metro Area

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by:

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LIST OF ACRONYMS/ABBREVIATIONS

AHS	Automated Highway System
APTS	Advanced Public Transportation Systems
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
AVCS	Advanced Vehicle Control Systems
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CIMC	Colorado Incident Management Coalition
CSP	Colorado State Patrol
CTI	Colorado Transportation Institute
c v o	Commercial Vehicle Operations
DAB	Digital Audio Broadcasting
DIA	Denver International Airport
DRCOG	Denver Regional Council of Governments
EON	Enhanced Other Networks
ESS	Environmental Sensor Systems
FHWA	Federal Highway Administration
FMCS	Fleet Management and Control Systems
FTA	Federal Transit Administration
GPS	Global Positioning System
HAR	Highway Advisory Radio
HOV	High Occupancy Vehicle
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
IVHS	Intelligent Vehicle Highway Systems
MAC	Metro Area Connection (Light Rail)
MOVA	Modernized Optimized Vehicle Actuation
OPAC	Optimized Policies for Adaptive Control
RDS	Radio Data System
RTD	Regional Transportation District
SCATS	Sydney Coordinated Adaptive Traffic System
SCOOT	Split, Cycle, and Offset Optimization Technique
TMC	Traffic Message Channel
TOC	Traffic Operations Center
TP/TA	Traffic Program/Traffic Announcement
TSM	Transportation Systems Management
VMS	Variable Message Signs
VMT	Vehicle Miles Traveled

DENVER METRO AREA IVHS STUDY

Master Plan

1. OVERVIEW

1.1 Introduction

The Denver metropolitan area currently faces a number of challenges in providing an adequate transportation system. The area is experiencing near-record population growth, but the available funding for infrastructure is not keeping pace. Denver is a non-attainment area for air quality and must reduce emissions. Air quality regulations also restrict Denver's ability to increase the capacity of the highway network. Realistic responses to these challenges must recognize the key role of transportation in the economy and its importance to the quality of life. All of these forces mandate that Denver find ways to increase the efficiency and effectiveness of the surface transportation system. Intelligent vehicle-highway systems (IVHS) technologies have been identified internationally as having significant potential as tools to enhance highway mobility and safety in the face of these greater social, environmental, economic and geographic restrictions.

IVHS comprises advanced transportation technologies in two broad areas:

- ***Smart vehicles***, in which advanced technology units operate independently on individual vehicles.
- ***Smart highways***, involving the installation of advanced technologies within the highway infrastructure.

The result of IVHS will be a ***smart traveler***. IVHS provides the infrastructure to collect and disseminate real-time travel information. For example, before leaving home, work or other locations, travelers could be able to determine congestion on their route (and choose another one or delay their trip), find out when the next bus/train will arrive at the nearest transit stop, or be matched into a carpool or vanpool for their trip. If they decide to drive an automobile, a route guidance system can inform them of the best path to follow to their destination.

There is no simple answer to the set of complex transportation problems that confront us, but IVHS technologies can help enormously. In the past decade, advancements in computers, micro-electronics, satellite technologies, and the emergence of cellular telephones have changed the way we think and communicate. IVHS unites these technologies and others with our transportation system to save lives, save time, and save money.

This document presents a Master Plan for the consideration of intelligent vehicle-highway systems (IVHS) technologies in the Denver area. A primary goal of the Denver Area IVHS Study is to identify the most promising and effective IVHS technologies for potential use in addressing the Denver region's transportation problems.

This Master Plan is intended to provide a "toolbox" of potential IVHS opportunities for transportation agencies to consider in addressing specific problems in the Denver area. In providing a broad range of IVHS activities that could yield measurable benefits for travellers, the Master Plan presents a very ambitious view of what can be accomplished. Obviously, not every concept can be implemented, but the plan identifies likely opportunities that should be monitored closely for their applicability to Denver. The plan is broad and flexible so that it can be kept current with the rapidly evolving technology available. Research and development, field trials, and operational tests are already being conducted on promising IVHS technology throughout the United States and the world.

This document also serves as an internal planning reference to assist the Colorado Department of Transportation (CDOT) in the organizing and prioritizing potential IVHS activities. The Denver Area IVHS Study process has already assisted CDOT in organizing their activities to help initiate and promote IVHS projects. Business plans which identify specific short-range opportunities and projects are being developed for statewide and regional IVHS programs. This document will provide additional guidance for these efforts.

The Master Plan also has potential to be used as a marketing tool by CDOT in the solicitation and creation of public/private partnerships. The private sector will have a large impact on the implementation of IVHS. CDOT and local agencies have very little money to devote to IVHS projects, and what funds are available will need to be used to leverage Federal and private funds. Working closely with private companies to develop partnerships and implement infrastructure and services will be vital.

1.2 Potential Benefits of IVHS in the Denver Area

In a recent review of 38 major studies of IVHS projects around the country, the General Accounting Office (GAO) found that the effects of IVHS are positive and promising, based on limited data (Reference 1). "The major studies have a high degree of consensus that these technologies can not only improve mobility but, under certain configuration, could also achieve other policy goals of economic benefits, improved safety, energy conservation, and air quality." For example, an evaluation of the Chicago Area Expressway Surveillance and Control Project (Reference 2) showed a 60% reduction in peak period congestion, an 18% reduction in accidents, expedited emergency responses, and a benefit-cost ratio of 4: 1. Similar benefits have been documented for the ramp-metering system in Denver (Reference 3).

There are two types of congestion on freeways: recurrent and incident-related. Recurrent congestion is typically associated with the peak commute period. It is basically caused by demand which has built to a point where it nears or exceeds capacity. Incident-related congestion normally occurs as a result of a temporary lane closure; these can be caused

by accidents, stalls, flat tires, or spilled loads. It is estimated that 60 percent of all motorist delay is incident-related (Reference 4). A study of incidents in Los Angeles found that, under off-peak free-flow conditions, 4 or 5 minutes are added to the duration of congestion for each additional minute that a lane blockage is allowed to continue (Reference 5). The Colorado Incident Management Coalition was formed in September, 1992 to address these problems. This group's final report (Reference 6) recommended over 26 actions, many of which would be enhanced by or rely on NHS technology deployment in the Denver area (Examples include Traffic Operations Center, electronic surveillance, closed-circuit TV, cellular phone calls from citizens, etc.). These can improve detection, verification, and response to incidents and give motorists better information about conditions. Chicago's incident management program returns about \$17 in benefits for each \$1 invested in the program (Reference 2).

IVHS America has recognized the necessity for better evaluation of IVHS applications, operational tests, deployments, and systems. Guidelines are being developed so that operational test programs will treat the evaluation of project results as a major project goal (Reference 7). Denver IVHS efforts will rely on this national experience, and IVHS project planning and funding requests will also include an assessment of the potential benefits to be expected from individual projects. This will help regional policy makers compare the benefits to be derived from money spent on IVHS projects as opposed to other worthy projects which may solve problems from a different aspect.

1.3 The Denver Area IVHS Study

The Denver Area IVHS program can be broken down into the following key components:

- Early Action Plan.
- Strategic Plan.
- Denver Traffic Operations Center (TOC).
- Communications Network Plan.
- Master Plan.

The Denver Area IVHS Study presents an excellent opportunity for the Colorado Department of Transportation (CDOT) to take a lead role in applying a comprehensive approach toward developing technology solutions to both current and future transportation needs. The program will also seek to promote and develop important working relationships between different agencies and jurisdictions in the Denver area. Further relationships are expected to develop between the public and private sectors in pursuing IVHS ventures, in line with national policies and program opportunities. Overall, the IVHS study provides opportunities for improved highway transportation, increased economic prosperity and the establishment of the Denver region as a center of excellence in IVHS.

1.4 Denver Area Master Plan

The primary role of the Master Plan within the IVHS study is to bring together the activities defined in the Early Action Plan and Strategic Plan into a single, integrated program. The Master Plan aims to identify which IVHS activities are likely to be of greatest benefit and defines how to apply them. It also outlines an implementation plan that can be brought forward for securing funding within CDOT, as well as exploring opportunities for Federal Highway Administration (FHWA) and private sector involvement.

The Master Plan will help CDOT take a lead role in the development of a seamless transportation network for the Denver area by coordinating and unifying the efforts of the appropriate city, county, state and Federal agencies. Overall, the Master Plan will serve as a strategic level document for planning, scheduling and implementing IVHS activities throughout the Denver region.

1.5 Master Plan Design Process

The Denver Area Master Plan provides the overall framework for implementing activities from the appropriate IVHS functional areas and related incident management programs. The implementation of the Master Plan will best be realized by a logical, incremental program approach. This approach will highlight the impacts of introducing IVHS in the following areas:

- Improved safety of surface transportation.
- Increased credibility of traveler information,
- Increased highway capacity, efficiency and predictability.
- Enhanced personal mobility throughout the Denver area.
- Improved interjurisdictional cooperation.
- Rapid response to incidents.
- Improved intermodal coordination.
- Reduced environmental and energy impacts.
- Increased public-private partnerships.

In scheduling activities, the Master Plan is divided into phases during which IVHS functions and services can be incorporated over time as technologies and funding become available. A brief overview of activities in each of these phases is presented below.

1.5.1 Short-Term Operational Phase

The short-term phase of the Master Plan will focus primarily on those systems already operating in the Denver area and their potential upgrade, enhancement and integration with other IVHS-related services. In addition, this period will include the design, construction and implementation of the permanent Denver Area Traffic Operations Center (TOC). Prior to commissioning of this facility, an interim TOC will be established to coordinate ongoing activities and develop operational strategies for use of initial systems.

Within the short-term, the Master Plan calls for a reliable, extensive and comprehensive information collection system to be established. This will provide the foundation for the Denver area's Advanced Traffic Management System (ATMS) efforts. Regionwide surveillance will enhance the Denver area's coordinated incident management approach and improve inter-jurisdictional cooperation between the involved local agencies. Traffic data collected at the TOC will also support network analysis and planning efforts in areas such as congestion management.

The Denver area short-term Advanced Traveler Information Systems (ATIS) activities will introduce both in-vehicle and pretrip traveler information services. These will provide numerous opportunities for the formation of public-private partnerships and the establishment of valuable ties with local media agencies. Further efforts to consolidate the area's communications network will establish a high level of information credibility and improve day-to-day traffic and incident management.

1.5.2 Medium-Term Operational Phase

The medium-term operational phase will build upon the foundation established within the short-term timeframe. This time period will see a continuation of ATMS, incident management, ATIS and communication activities, as well as phased implementation of new activities which possess advanced IVHS features.

As the Denver area extends its ATMS operations in the medium-term, information will be collected from vehicles, roadway sensors, traffic control systems and distributed traffic information centers. With more sophisticated sensing and communications equipment becoming available, improved interpretation of the incoming data and dissemination of the processed information will result from enhancements to computer operations at the Denver area TOC.

Increased processing capabilities, new forms of artificial intelligence, multiple database integration, data fusion principles and expert systems will all provide valuable operator decision aids as well as fully-automated responses to repetitive tasks. In parallel, new ATIS technologies and systems will improve traveler dissemination strategies, providing more useful information to the traveling public, and reducing response times for emergency situations.

1.5.3 Long-Term Operational Phase

IVHS technologies have advanced beyond recognition from their predecessors over the past few years. With IVHS now a major focus of national and international attention, even greater changes can be expected in the years ahead.

As technologies advance, new techniques concerning traffic operations and management, traveler information dissemination and incident management activities can be evaluated for inclusion within the Denver area. The most appropriate approaches will be incorporated as they are proven. Potential areas of activity include interactive traffic signal control, and phased deployment of Advanced Vehicle Control System (AVCS) approaches.

In addition to any new systems and technologies, it is anticipated that an ongoing enhancement of the communications network will be undertaken in the long-term. This effort will not only support regionwide operations, but will also support the ultimate realization of a statewide, seamless IVHS network.

1.6 Organization

After this introduction, the Master Plan is divided into four further chapters and an appendix which address key issues concerning IVHS in the Denver metro area. The content of these chapters is as follows:

- Chapter 2 - Goals and Objectives. This chapter outlines the key goals and objectives of the Denver area IVHS study.
- Chapter 3 - Master Plan. This chapter introduces a phased implementation program for local IVHS activities. It provides a descriptive picture of the way IVHS will develop in the Denver region.
- Chapter 4 - Activity Coordination. This chapter establishes guidelines for coordination of the IVHS program with existing systems in the area and other current IVHS activities in Colorado. It also assesses the need to coordinate with national IVHS efforts.
- Chapter 5 - Summary. This chapter presents an overall summary of the Master Plan and the future of IVHS in the Denver area.

Finally, Appendix A provides detailed summaries of each component IVHS effort included in the Denver area program. It presents a consistent approach for deploying the Denver area's IVHS activities within a phased implementation program.

2. GOALS AND OBJECTIVES

2.1 Introduction

The 2015 Interim Regional Transportation Plan (RTP) (Reference. 1) was recently adopted for the Denver metropolitan area. This document concludes that the region will grow faster than the transportation system can be expanded. The plan is financially constrained, and only one-third of the improvements needed to maintain the current level of mobility can be funded. In addition to some new transportation facilities and services, the plan identifies management activities which will be necessary to efficiently operate the existing system since new construction will be a relatively minor component. New facilities must be actively managed to ensure continuing efficient operations of these facilities. IVHS has been grouped as a component of congestion and travel demand management activities which were specifically identified for funding between 1994 and 2015.

In addition to addressing regional mobility concerns, this Master Plan represents a component of the Denver area's contribution to the national IVHS effort, as well as a guiding document for regional IVHS application. Goals for the project can therefore be defined by examining the key themes of this national initiative and relating them to this study. From this foundation, the goals and objectives of the Denver area's overall IVHS Study and Master Plan can be identified.

2.2 Denver IVHS Study

2.2.1 Regional Framework

M-IS should be implemented in the Denver area in a manner which addresses the current and future concerns about regional congestion and mobility. The RTP has determined that most of the freeway system will be more than 15% over capacity in 2015 with the remainder at 1-15% over capacity. In addition to the RTP, DRCOG is currently developing a Congestion Management System (CMS). The intent of the CMS is to provide for effective management of existing and new transportation facilities through the use of travel demand reduction and operational management strategies (Reference 2). The functions which the CMS will address include:

- Manage existing and new facilities to provide the best utilization possible.
- Develop, evaluate, and recommend congestion strategies.
- Monitor and analyze congestion.

Through the RTP and CMS efforts, the region will be pursuing operational management strategies that maximize the safety, capacity, utilization, and efficiency of transportation facilities. IVHS' internationally recognized potential to improve transportation operations within these areas implies a close relationship between IVHS and the two current efforts. IVHS implementation in the Denver area is expected to take place within the overall of the RTP and CMS, as another potential tool to address congestion and mobility problems

in the Denver region. IVHS will also be able to provide monitoring information and other tools to assist in the implementation of components of the RTP and CMS.

There are a number of specific regional goals in the RTP to which IVHS can make a significant contribution, including:

- Increase the regional system's capability to efficiently move people and goods.
- Pursue mobility management techniques which encourage ridesharing and travel during non-peak hours.
- Emphasize techniques to manage, adapt, and reconstruct the region's existing transportation system to better use available capacity. Give priority to maintenance and management improvements for existing facilities to protect previous investments.
- Develop management systems and consider their recommendations in the Transportation Improvement Program.
- Make major transportation corridor operations more efficient by implementing intelligent vehicle/highway system (IVHS) strategies.
- Encourage public/private partnerships in providing facilities identified in the RTP.
- Incorporate appropriate travel demand reduction and operational management strategies when implementing capital improvements.

2.2.2 IVHS Goals

The primary goal of IVHS implementation in the Denver area is to help maximize the efficiency and safety of the existing and planned components of the surface transportation system. During the Denver area IVHS study, specific goals have been developed for IVHS in each of the four following categories:

- Transportation Operations.
- . Management Issues.
- Economic Concerns.
- Environmental Issues.

Transportation Operations Goals

- Reduce traffic congestion on regional freeways and arterials and improve regional mobility. The Denver Regional Council of Governments (DRCOG) and other agencies in the Denver area are currently developing a regional congestion

management system (Reference 3). IVHS activities in the region should be responsive to the recommendations of this CMS effort.

- Increase transportation safety (National estimates place the benefits of deploying IVHS technology at 8 percent reduction in traffic fatalities within the next 20 years) (Reference 4).
- Minimize the effects on nonrecurring incidents on travel safety and efficiency. Specific IVHS activities have been identified in the recommendations of the Colorado Incident Management Coalition (Reference 6).
- Support and enhance transit operations as well as other alternative modes and trip reduction measures.
- Integrate future IVHS activities with existing ramp metering, transit operations, HOV facilities, incident management programs, intercity signal coordination programs, arterial coordination programs, and other existing traffic management measures.
- Positively influence travelers' decision-making by providing accurate real-time travel information.
- Provide system performance monitoring tools, data, and other information to support the implementation of congestion and traffic management systems.

Management Goals

- Demonstrate that interagency cooperation and coordination can be effective in the Denver area.
- Demonstrate that IVHS projects can successfully cross jurisdictional boundaries.
- Provide information to educate transportation professionals, the public and political decision makers of the potential benefits of IVHS in Colorado.
- Create an environment which encourages and actively solicits private sector participation and commercial involvement in CDOT's IVHS activities.
- Provide opportunities for academic research and participation.
- Help establish Colorado as a high technology leader.

Economic Goals

- Demonstrate efficient use of tax dollars.

- Develop IVHS in the Denver area in a “fast-track” manner to take advantage of Federal funding available through the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).
- Make maximum use of existing, proven technologies to ensure high benefit-cost ratios.
- Facilitate private sector financial participation in areas of mutual benefit to both public and private interests.
- Minimize new construction and maintenance costs through IVHS applications.

Environmental Goals

- Contribute to regional air quality enhancement goals.
- Reduce the need for additional laneage and the environmental impacts thereof, by achieving operational improvements through technological methods.
- Reduce environmental impacts from roadway hazardous material spills through IVHS activities such as a coordinated incident management program.
- Reduce the Denver area highway system’s vulnerability to disruption by weather-related environmental conditions.

2.2.3 Objectives

This section outlines possible strategies which will help to realize the goals listed above. These can be grouped under a number of global objectives, as follows:

- 1) Provide a focal point for the Denver area’s IVHS activities. This objective concentrates on the design, construction and implementation of the Denver area TOC. The TOC and its associated activities will be central to the region’s IVHS-related data collection, computer processing, incident management and information dissemination techniques.
- 2) Improve the coverage and scope of traffic data collection. This objective focuses on techniques which will enhance and expand the current local transportation information collection systems. It explores alternative technologies to improve data collection facilities along both the freeway and arterial road networks.
- 3) Develop computerized data handling and monitoring systems. This objective is concerned with the use of computer peripherals and processes to collect, store, analyze, and disseminate IVHS information. All computer systems should employ open architecture and standards to ensure future compatibility. Many of the ATMS and ATIS projects included in this Master Plan will rely on database integration and data fusion techniques to produce consistent and reliable databases.

- 4) Improve incident detection and response. This objective concentrates on improving the area's incident detection, response and management capabilities through IVHS applications. It seeks to involve a variety of resources in this venture, including local agencies, Courtesy Patrols, media traffic information services, the private sector, and the motoring public.
- 5) Create a regionwide IVHS system communications network. This objective focuses on the planning and deployment of communications facilities to link the IVHS elements deployed in the Denver area. Short-term objectives include realization of a temporary network through integration of existing data channels, identification of key communication locations and investigation of communications media alternatives. In the future, "empty" conduit will be installed with freeway widening and other construction projects in order to minimize the costs and disruption of installing the future communications network. The permanent communications network will build upon this foundation as the program continues.
- 6) Disseminate travel information regionwide. This objective involves various methods and technologies for communicating traveler information throughout the Denver area. The services deployed will aim to provide the traveling public with real-time, en-route and pretrip information. Efforts will focus on integrating existing systems as well as identifying new information service opportunities appropriate for private sector participation.
- 7) Improve and integrate traffic control systems. This objective concentrates on improving existing arterial and freeway traffic control systems, integrating new systems with existing, and integrating the Denver area's freeway IVHS initiatives with those of its arterial street system. Efforts will focus on establishing new systems and communicating with them, improving operations of existing systems, and evaluating methods to make all systems work more efficiently together. Special attention should be paid to integrating arterial and freeway systems, and evaluating control scenarios for use during incident diversions.
- 8) Reduce travel demand and enhance attractiveness of alternate modes of travel. This objective focuses on integrating multi-modal initiatives within the region's overall IVHS program. It involves investigation of integrated demand management techniques, rideshare matching systems and transit initiatives, as well as continued partnership activities between CDOT, the Regional Transportation District (RTD) and DRCOG.
- 9) Implement a program management system. Activities within this objective address the broad requirements of management for the IVHS program in the Denver metro area. These include coordination of the main technical projects, mechanisms for addressing policy and legal issues, development of project evaluation guidelines, and standard-setting activities. These program management tasks will be ongoing throughout the course of IVHS implementation.

2.3 Master Plan

The Denver area Master Plan will serve as a resource document for the local implementation of IVHS activities. Current programs in the Denver area and the unique local socioeconomic, physical and transportation environments have been critical inputs in the development of this document. The following outline describes the purpose of the Master Plan:

- 1) To identify the most promising and effective IVHS alternatives, technologies and operational strategies for implementation within the Denver area.
- 2) To combine the activities defined in the Early Action Plan and Strategic Plan into a single, integrated program.
- 3) To develop a phased implementation program for IVHS activities in the Denver area that recognizes the combined and individual interests of CDOT and local agencies, together with the opportunities and constraints of each activity.
- 4) To detail and expand on the IVHS activity descriptions from the Early Action Plan and Strategic Plan in terms of each activity's overall role in the program and interrelationships with other efforts.
- 5) To develop outline scopes of work for the various IVHS program activities.
- 6) To identify preliminary implementation time schedules and associated cost estimates for the IVHS activities.
- 7) To highlight the responsibilities of state, local and Federal agencies and the private sector in planning and implementing each activity.
- 8) To identify potential funding sources for each activity.

Next, Chapter 3 provides a more detailed explanation of how the Master Plan seeks to achieve the identified goals and objectives. For further information on specific activities, the reader is referred to the individual project descriptions included under separate cover as Appendix A.

3. IMPLEMENTATION PLAN

3.1 Introduction

This chapter of the Master Plan presents a recommended course of action for the development and deployment of selected IVHS approaches and technologies in the Denver area. The chapter serves as a guide for implementing the activities outlined in both the Early Action Plan and the Strategic Plan. The Master Plan represents an integration and expansion of these two documents. Overall, this chapter provides a descriptive picture of the way IVHS can develop in the Denver region, as well as an outline of how various activities could fit together.

3.2 Implementing IVHS

Implementing IVHS in the Denver metropolitan area (and for the entire State of Colorado) will require a concerted effort by many elements of the transportation community. Colorado's portion of federal funding was not improved under ISTEA, and the state will receive less money under ISTEA than it did previously. Thus, IVHS will likely face intense competition from more traditional activities for funding.

IVHS must build support and alliances so that decision-makers at all levels realize that IVHS has a role in enhancing the operations of a balanced transportation program. Implementing a successful IVHS program will include the following elements:

- Build support for IVHS,
- Expand current projects,
- Form alliances with other agencies,
- Develop partnerships with the private sector,
- Implement high priority, high visibility projects, and
- Solve current metro-wide problems.

3.2.1 Build Support for IVHS

Initial and continuing support for IVHS will come as a result of coordinated efforts from individuals and agencies and the perceived levels of success of the early action IVHS projects. Transportation decision-makers must see that money invested in IVHS benefits users of the transportation system as much as traditional roadway improvements (additional lanes, reconstruction, etc.). IVHS must initially develop and nourish "champions" (especially within CDOT) who will give IVHS the "benefit of the doubt" when the technologies are in their infancy.

3.2.2 Expand Current Projects

As described in the following section, there are a number of ongoing projects and programs which provide a solid basis for implementing IVHS. For example, the ramp metering programs along I-25, I-225, and I-70 were implemented to improve traffic flow along these freeways. In addition, they provide real-time information about traffic speeds, traffic volumes, and the quality of operations. This information is currently utilized by

a private traffic reporting service to broadcast more complete traffic condition information over commercial AM and PM radio. CDOT will improve the utility of this traffic information in the near future by updating the system software and creating a graphical display of freeway speeds.

The North I-25 Bus/HOV facility will provide the first segment of freeway in Denver which has nearly complete IVHS capabilities. This facility will eventually include closed circuit television (CCTV), variable message signs (VMS), inductive loops, and active systems management (because of the reversible nature of the operations). CDOT will be responsible for ongoing operations which will provide valuable experience in ATMS/ATIS operations.

IVHS could eventually become an important element in getting travellers to the new Denver International Airport (DIA). This has been the subject of concern throughout the metro area since the new site was selected. Ramp metering should be expanded along I-70 and I-270 to improve operations on the freeways leading to the new airport. Many of the programs identified by the Colorado Incident Management Coalition (CIMC) can be supported by IVHS. Corridor Management Teams are already working along I-70 and the northern accesses to DIA. The Courtesy Patrol could also be expanded along I-70, particularly just east of I-25 where there is little shoulder room for breakdowns along the elevated portion.

RTD (in partnership with CDOT and the Westinghouse Corporation) has been selected by the United States DOT for two IVHS operational test projects. The purpose of both is to assess the influence of real time transit information and whether this information will affect the traveler's choice of mode. The first element will provide real time bus departure information on television monitors located at a number of major bus transfer points, Park-n-Rides, and at the Denver International Airport (DIA). RTD's automatic vehicle location (AVL) system will be utilized to update arrival and departure information on screen, similar to techniques used by the airlines. The second element of the project involves enhancing transit information sent to selected companies participating in the EcoPass program. (EcoPass is an annual bus pass which businesses provide for employees as an alternative to driving to and from work. Because the pass is offered to many employees, the price per pass is low. The pass allows the holder to use any RTD service and also includes a "Guaranteed Ride Home" by taxi in case of emergency or other unusual circumstance.).

3.23 Form Alliances With Other Agencies

CDOT has already initiated the formation of alliances with other agencies to further the goals of IVHS. The most visible alliance was the Colorado Incident Management Coalition (CIMC), which brought together a diverse group of safety, emergency response and operating agencies and private sector interests. On-going efforts have focused on developing alternative access to the new airport, continued support for the Courtesy Patrol program, formation of corridor management teams, and initiation of legislation to assist in incident management. The work of this group and its recommendations meld very well with the IVHS program.

As direct result of CIMC cooperation, the Colorado State Patrol (CSP) has already been working with CDOT to coordinate planning, operating, and staffing issues for both the interim and permanent Traffic Operations Centers (TOC). The TOC will be CSP's dispatch center for northeastern Colorado. CDOT and CSP are investigating ways to consolidate TOC operations so that dispatching (both CSP and CDOT maintenance operations), incident response, and IVHS related activities will operate from a common staffing and personnel system. This would represent a unique consolidation of TOG functions in the United States at the present time.

In addition, CDOT has worked closely with the Regional Transportation District on the North I-25 Bus/HOV project, the I-70 Hogback Multi-modal Transfer Facility and the real time transit information operational test. There will be a continuing need for cooperation and coordination as these projects move into implementation and operations. RTD has undertaken several other IVHS-related projects that will benefit from this coordination. The AVL system referred to as part of the operational test is being installed on all RTD buses. In the future, buses could serve as probes on the freeways to automatically provide speed data. The drivers could also relay information about conditions and incidents via the radio system. The accuracy of the information about bus schedules and traffic conditions could improve with links to CDOT's Traffic Operations Center. CDOT's and RTD's intent will continue to be improving efficiency of the entire transportation system and improving utilization of transit by giving travelers more accurate, real-time information.

The IVHS program can help address other high priority, metro-wide concerns through close coordination with DRCOG as well as RTD. DRCOG is currently developing a congestion management system, as mandated by ISTEA. There will be increasing needs to reduce traffic demands and shift more travel demand to higher occupancy vehicles. IVHS technologies can give travelers accurate, real-time information at home or work so they can make informed decisions. This can augment the current carpooling program jointly sponsored by DRCOG and RTD.

Finally, CDOT must continue to closely coordinate IVHS projects with the local traffic engineering community. Traffic engineers are well represented on DRCOG's Transportation Advisory Committee. This committee reviews, recommends and prioritizes regional transportation projects and needs to be kept current on potential Denver IVHS projects and their funding requirements. In addition, a number of city and county traffic engineers were represented on the Technical Advisory Committee for this IVHS study. These efforts must continue during design and implementation of the Traffic Operations Center. Denver's freeway links are CDOT's responsibility but many of the intersecting arterial links are under local jurisdiction. Many of the future IVHS improvements to both roadway networks should be closely coordinated. This is formally underway with the ongoing work of the Corridor Management Teams along the freeway corridors. Better coordination of the ramp metering systems and local signal system along the intersecting arterial will improve operations on both systems. This improved flow and coordination can also help to improve air quality.

3.2.4 Develop Partnerships With The Private Sector

CDOT has embarked on an ambitious IVHS program for the entire state. As with many areas of providing services to the public, the needs far outstrip the financial resources available. In order to make most of its limited resources, CDOT would like to change the way it conducts business and involve the private sector to a much greater degree. Traditionally, CDOT and other public agencies identify project priorities and budget money for planning, design and construction. Private companies can be involved at one or all of these stages. Now, CDOT wants to move beyond this framework. In order to leverage its limited resources, CDOT wants to involve the private sector in all stages of the process: the identification of feasible projects, setting priorities for their implementation, joint development of infrastructure, interactions with the public, etc.

CDOT wants to create public/private partnerships to implement IVHS, while fully recognizing that there may be philosophical differences in the approaches of the public and private sectors: the public sector's focus is service delivery, while the private sector is interested in profits. CDOT would like to consider various types of partnerships. These could include the following options: (Reference 10)

- Functional division of responsibilities, where the public sector collects information both for its own use and for sale to private firms.
- Franchised operations, where the public sector still collects data, but then awards either exclusive or nonexclusive franchises to one or several private companies. The franchise would then disseminate the data while the public maintains regulatory controls.
- Completely private operations, in which the entire system is privately operated.
- Publicly owned systems operated by private contractors, where the public sector finances and deploys the system and specifies the performance standards for operation. A private company(s) would determine the hardware and software necessary to meet these requirements.
- Unified public/private partnerships, where both parties collect information, which is then funneled to a central location for dissemination to clients, using both public and private transmission facilities.

CDOT recognizes the importance of future private sector participation in IVHS and has already initiated private sector outreach activities. In June, 1993, CDOT conducted an IVHS seminar for approximately 100 CDOT and private sector attendees, at which existing Colorado IVHS activities, funding levels, philosophies and concerns were discussed. In September, 1993 CDOT sent the seminar attendees a Request for Information (RFI) in an attempt to gather additional information and ideas from the private sector. The RFI results will eventually be used to develop specific Requests for Proposals to form cooperative agreements with CDOT to improve transportation efficiency and safety.

For the foreseeable future, CDOT's IVHS activities will primarily consist of gathering, analyzing, and disseminating information about the transportation system. The private sector can assist in defining services that are valuable enough that people will be willing to pay for them. This cooperation can help identify information and services which are

high priority. Communications is another possible area where partnerships might be forged. The IVHS system will require a fiber optics network along the freeways. Use of CDOT's right-of-ways by private networks in exchange for use of fibers could form the basis of a partnership. The next section identifies a number of potential projects which can be implemented in the short-term if funding is available. Private partnerships which promote specific projects or activities should be a key indicator of potential citizen support.

3.2.5 Implement High Priority Projects

The Early Action Plan identified the highest priority IVHS project as the design and implementation of a Traffic Operations Center (TOC). The TOC is the foundation for metro and state-wide IVHS activities and will provide a focal point for data collection, information dissemination, traffic management and incident response activities. The TOC could also provide opportunities for multi-jurisdictional cooperation, education and research, and partnerships with the private sector. CDOT has already budgeted funds for an interim TOC which will provide working experience directly applicable to the implementation and operations of the permanent TOC.

Advanced communications capabilities are a key component of almost all IVHS activities. CDOT will install a backbone communications network along the freeway system for closed-circuit television (CCTV), variable message signs (VMS), highway advisory radio (HAR) broadcast, various data collection functions, and future ATIS and AVCS activities. As outlined in the Communications System Conceptual Plan, conduit should be included in any CDOT construction projects along Denver's freeways. Special projects should also be funded to build onto the North I-25 Busway fiber optic system, starting with the Bus/HOV extension along US 36.

3.2.6 Help Solve High Priority Problems

As mentioned above, IVHS can be an important factor in improving access to the new Denver International Airport. I-70, I-270, I-225, 104th Avenue, and eventually 120th Avenue and E-470 will provide alternative access to the airport. Incident management techniques, as outlined in the CIMC final report, can help smooth traffic flow along these routes. These roads should be given priority in deploying observation and information equipment (CCTV, VMS, HAR, etc.) on Denver's freeway network. CDOT anticipates working with the City and County of Denver, Adams County and Denver International Airport to evaluate appropriate IVHS technologies for implementation along DIA access roads.

Other possible corridor projects which would involve multi-agency coordination and cooperation include improvements to US 36, the Southwest Corridor (along Santa Fe Drive), and the sports complex area near downtown RTD has a bus lane along US 36 and will be improving its utility and utilization when it ties into the North I-25 Bus/HOV facility. RTD is considering several IVHS-type corridor projects for US 36 which CDOT would likely participate in.

RTD is currently conducting the Southwest Corridor Alternative Assessment. There is an opportunity to coordinate improvements between the selected mass transit technology and Santa Fe Drive to promote multi-modal coordination. I-25, the MAC line, Santa Fe Drive, and Broadway/Lincoln all intersect in a very small area. Projects which coordinate transportation service at this focal point should be able to promote increased transit utilization and system efficiency.

There is also an Opportunity to coordinate traffic control for sports activities. Mile-High Stadium and McNichols Arena are located immediately west of I-25 and pre- and post-game traffic complicates freeway operations and safety. Improved warnings of traffic congestion and lane use advisories could improve safety. Coors Field, the new baseball stadium, will be located between the new 20th and 23rd Street Viaducts east of I-25. Based on 1993 attendance of about 57,000 per game, the 81 Colorado Rockies home games will also be crowded to the extent that traffic complications arise. Gameday traffic control and access to and from I-25 should be closely coordinated between CDOT and the City and County of Denver. Improved traffic monitoring, directional information to motorists, and variable messages signs could greatly improve congestion and help address air quality concerns. A sporting event control system could provide the basis for better, more responsive traffic control plans for other special events, as well as everyday traffic in the area.

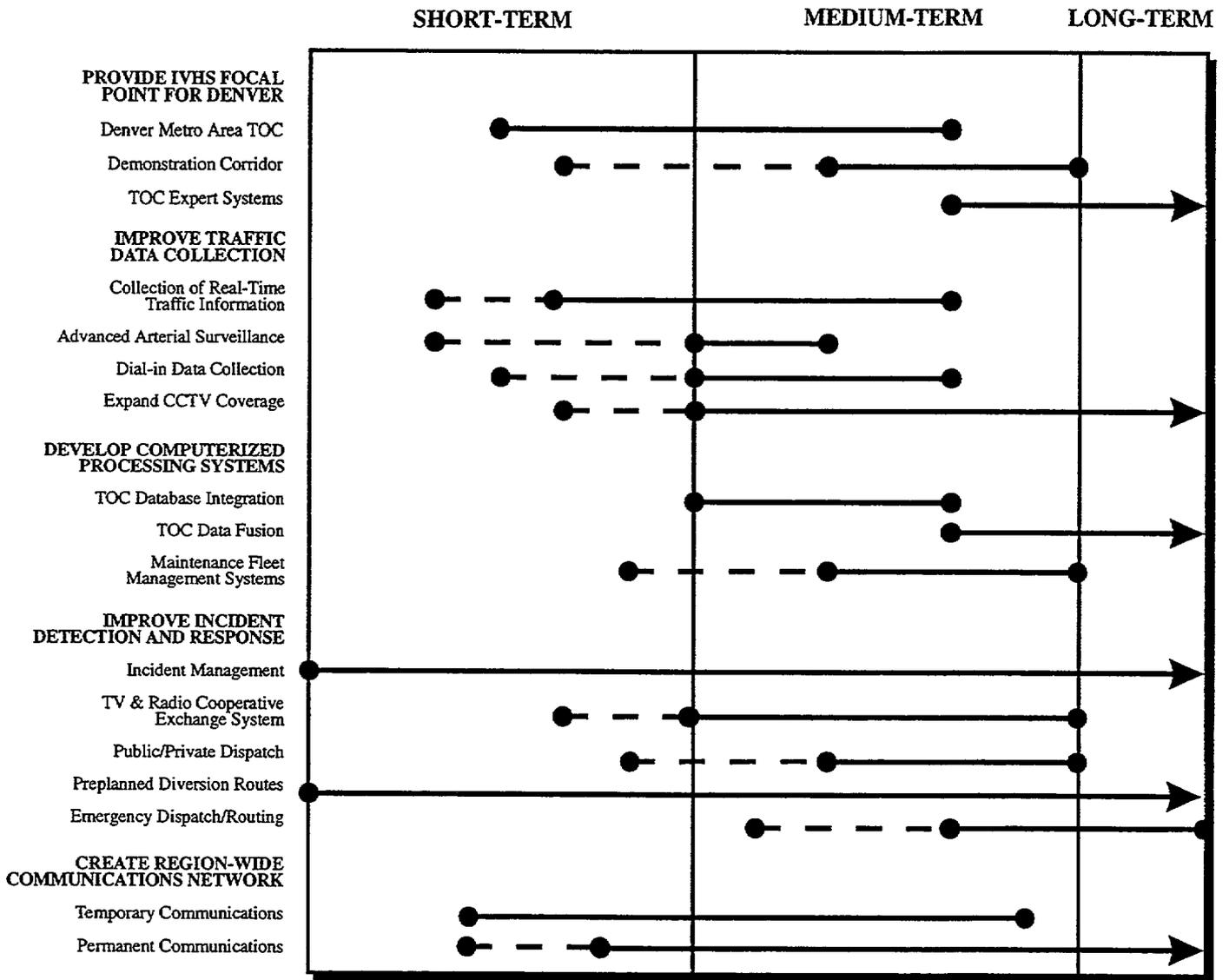
3.3 Activity Timetable

The Denver Area's IVHS program will best be realized by a logical, incremental program approach. Implementing the different activities which comprise the Master Plan depends on several factors: 1) development and availability of the underlying technology; 2) funding availability; 3) presence of, or potential for public private partnership; and 4) status of basic infrastructure or necessary previous projects. As mentioned before, CDOT will not have the human or financial resources necessary to pursue all of the projects mentioned in this document. Thus, public/private partnerships in particular will be a vital factor in determining which projects are tested, implemented or accelerated. This is particularly true of many projects which disseminate information to travelers (ATIS).

Activities comprising the Master Plan are divided into planning periods during which functions and services can be pursued over time as technologies and funding become available. The Master Plan timetable is broken down into three phases (based on normal funding sources) with the corresponding time periods as follows:

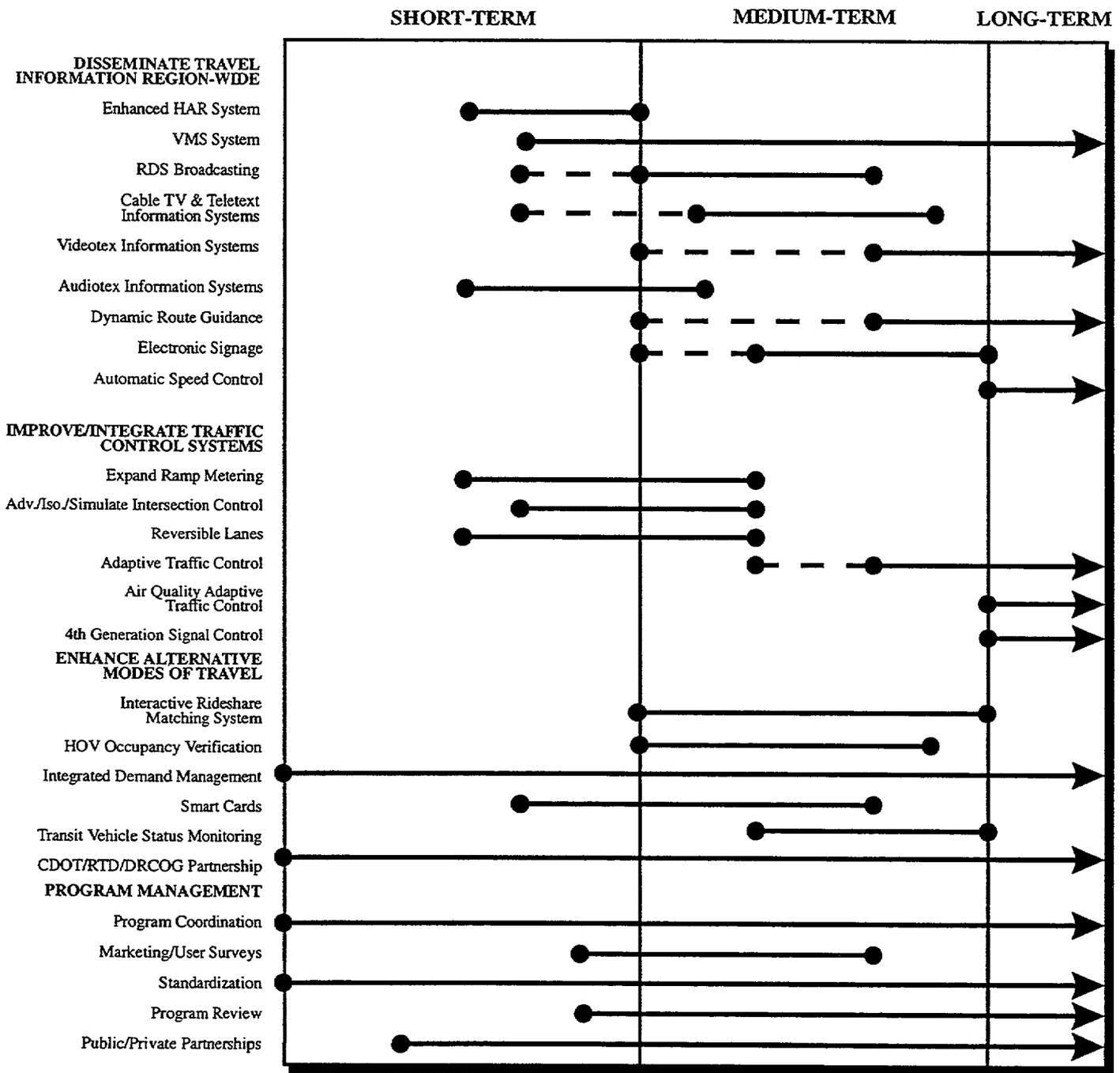
- 1) Short-Term Operational Phase (present through five years).
- 2) Medium-Term Operational Phase (five years through ten years).
- 3) Long-Term Operational Phase (beyond ten years).

Figure 3.1 depicts a potential implementation program for the Denver region based on the overall "toolbox" of IVHS projects in the Master Plan. This figure shows potential start times for the various projects (many of which could occur earlier through a public/private



--- Indicates Earlier Start
 Made Possible Through a Public/Private Partnership

Figure 3.1 Implementation Phasing Schedule



--- Indicates Earlier Start Made Possible Through a Public/Private Partnership

Figure 3.1 Implementation Phasing Schedule (Cont.)

partnership) within the short-term, medium-term and long-term planning periods. Potential IVHS activities are categorized within their respective Strategic Plan objectives as well as linked in an overall chronological order. They cover the possible strategies and associated IVHS activities which could help to realize the region's goals for transportation operations, management, and economic and environmental issues. Figure 3.1 also provides a look at activity interdependencies as well as a sense of continuation throughout the entire Denver Metro IVHS Program.

3.3.1 Short-Term Activities

It is envisioned that the activities listed below can establish the foundation for the Master Plan's short-term operations. Again, not all of these activities are achievable within this time frame due to funding constraints. Potential short-term projects could include:

- Continue existing IVHS activities and projects. An example is the Mile High Courtesy Patrol program initiated through the CIMC.
- Denver Area TOC implementation-(interim facility). CDOT has already begun initial planning efforts for the interim TOC.
- Collection of real-time traffic volume and speed information. Current CDOT updating of the ramp metering computer will make short-term enhancements to the ramp metering system much easier.
- Dial-in data collection system. Initial planning efforts are underway through the CIMC.
- TOC database integration. Work could be initiated following implementation of the permanent facility.
- Incident detection and management, Efforts are being continued through the CIMC.
- Cooperative information exchange with television and radio traffic information services. CDOT has already had initial discussions with several local media outlets.
- Public and private dispatch systems.
- Preplanned incident diversion routes. Initial work is underway through CIMC Corridor Management Teams in three locations, along I-25 south (Denver Tech Center Area), and for the north and south accesses to DIA.
- Temporary communications to key locations.
- Permanent communications network. The communications system being installed for the North I-25 Bus/HOV TMS will be used as a "blueprint" for the ultimate Denver area communications system.

- Enhanced highway advisory radio (HAR) network.
- Variable message signs (VMS). The initial series of VMS to be installed will be in the North I-25 corridor as part of the Bus/HOV TMS.
- Cable television information systems.
- Audiotex information systems.
- Expanded freeway ramp metering system. See information discussed under “Real time traffic volume and speed” activity.
- Advanced isolated intersection control and simulated signal coordination.
- Reversible lanes in key corridors.
- CDOT/RTD/DRCOG partnerships.
- IVHS management and coordination (short-term) including marketing and user acceptance surveys, participation in standardization, and additional work in continuing to develop public/private partnerships.

Initial efforts are underway for a number of the short-term activities, however the most important of these (for the long-term success of IVHS in Denver) is continuing work on the design and procurement of construction funding for the permanent TOC. The TOC will be the IVHS cornerstone for implementation of the medium- and long-term activities. Conversely, most of the short-term efforts listed above can be implemented without a TOC.

3.3.2 Medium-Term Activities

Building on the short-term deployment effort, the medium-term operational phase could see a continuation of many of the above activities. Untried activities appearing in the short-term list could also be initiated during the medium-term, if so desired. Again, limited resources preclude implementation of the complete list of projects during this period as well. The following activities will likely be feasible for the Denver area during the medium term:

- Denver Area TOC implementation (permanent facility).
- TOC expert systems.
- Advanced arterial surveillance.
- Expanded closed circuit television (CCTV) monitoring.
- Data fusion.

- Maintenance fleet management systems.
- Emergency service dispatching and routing.
- Communication links to other centers.
- Digital traveler information broadcasting.
- Teletext information systems.
- Videotex information systems.
- Dynamic route guidance.
- Electronic signage.
- Adaptive traffic control.
- HOV occupancy verification.
- Integrated demand management.
- Smart cards for transit fare payment.
- Transit vehicle status monitoring.
- Interactive rideshare management and matching system.
- IVHS management and coordination (medium-term) including an overall review of the success of IVHS in Denver in the short- and medium- terms, and an overall redirection of the focus of IVHS implementation for the remainder of the medium- and long-terms.

3.3.3 Long-Term Activities

Long-term IVHS program activities can build on efforts started in the short- and medium-term timeframes and could also reflect technical advances over the next few years. Approaches which seem appropriate for the long-term and consistent with the earlier elements of the program are:

- Automatic speed control.
- Air-quality-responsive traffic control.
- Fourth generation signal control.

3.3.4 Management Activities

Throughout the course of the IVHS implementation effort, various management tasks should be undertaken as ongoing activities. These tasks address a variety of issues which will support IVHS implementation efforts as well as promote IVHS initiatives to the public, local agencies and private sector. They include the following:

- Program management and coordination.
- Marketing and user acceptance surveys.
- Participation in standardization.
- Program review and redirection.
- Program and project evaluation.
- Institutional, policy and legal issues facilitation.
- Promotion of public-private partnerships.

Successful continuance of these efforts should promote a technically, institutionally and societally acceptable IVHS implementation scenario for the entire Denver area. These management activities are described in the Strategic Plan and are not discussed in detail in this document, which is primarily concerned with technical efforts.

3.4 Project Definition

In the previous section, potential IVHS activities for the Denver area were listed in accordance with their implementation timeframes. This section outlines the approach used to define each of the identified IVHS activities in terms of criteria such as component tasks, the overall level of effort, and appropriate program approach. Each recommended IVHS activity is defined as follows:

- Objective. This section addresses the goals and objectives of the activity in terms of the technology or service to be implemented, and the anticipated results and benefits.
- Priority. This section considers the importance of the activity within the overall IVHS implementation scheme in the region.
- Applicable IVHS Goals. The purpose of this section is to identify the relevant goals for the activity from the Strategic Plan and Chapter 2 of this Master Plan.
- Activity Interrelationships. This section highlights the dependencies and interrelationships between the activity in question and other components of IVHS.

- Approach. This section outlines the overall approach for undertaking the effort. It includes consideration of the lead responsible agency as well as other partner organizations. In addition, it discusses options for performance of the work.
- Scope of Work. This section presents the overall work scope as a series of tasks and subtasks associated with the complete realization of the activity.
- Project Schedule and Costs. This section assesses the activity in terms of an estimated implementation schedule and associated costs. Overall time schedules as well as different budgeting approaches are identified when necessary.
- Project Funding. This section allocates responsibility for seeking funding support and outlines potential funding sources and mechanisms.

Detailed summaries for each activity are presented in this format in Appendix A. These project summaries outline the critical issues affecting the design, development and implementation processes required for individual IVHS activities in the Denver area. The phasing of IVHS elements has been established so that earlier projects can contribute to the realization of subsequent activities in a coordinated, incremental effort. The activity descriptions in Appendix A highlight some of these principal relationships and interdependencies. This detailed overview will provide the Denver area with the necessary framework to implement IVHS throughout its entire timeframe. Review of these analyses will support informed decision-making concerning each activity's overall implementation timetable.

It is worth noting that there are often a variety of alternative approaches to undertake an individual IVHS effort. The project descriptions presented in Appendix A generally outline specific paths for the various activities. However, these should not be considered too rigidly. Rather, they should be thought of as guidelines which can serve as a starting point for project implementation. Changing circumstances or technical advancements may create opportunities for different, more advantageous deployment approaches, which should be integrated into the program as they are identified.

3.5 Integration with the Denver Area TOC

A variety of transportation agencies in the region recognize the need to develop common solutions to both current and future regional transportation needs. The activities described in this Master Plan reflect input from several different groups including CDOT, FHWA, RTD, DRCOG, CSP, and city and county governments. A consensus opinion among many of these agencies suggests that the establishment of the TOC will be instrumental to the overall success of IVHS in the Denver area.

TOC implementation is central to many elements of IVHS in the Denver area. The TOC will provide a focal point for these activities, thereby supporting the operation of an integrated transportation information system. In addition, the TOC has the potential to provide a platform on which to improve dialogue and cooperation between various Denver area jurisdictions with respect to traffic operations and emergency response.

The establishment of the TOC is consistent with the recommendations of the C-Star plan (Colorado's statewide IVHS program) as well as the CIMC. In addition, this activity builds directly upon the recommendations of the Strategic Plan and Early Action Plan. The importance of the TOC will continue from the short-term phase throughout the duration of the implementation timetable, continuously expanding its role in supporting and controlling available and emerging IVHS technologies.

The TOC will be a multi-jurisdictional, multi-agency facility which will serve many purposes. These include the following:

- The TOC will be a focal point for multi-agency and public/private sector traffic management efforts. Operators will be able to monitor and control traffic flows on area freeways and ultimately influence traffic flows on the arterial street network. Data collected at the facility will support real-time operations as well as planning and analysis functions.
- The TOC will serve as a foundation for short-, medium- and long-term IVHS activities in the Denver Metro Area.
- The TOC will be a regional incident detection and response center. Coordination of local incident management initiatives will take place under one roof. TOC capabilities will include automated detection of incidents, initiation of response plans including transmission of advisory messages to the appropriate agencies, and the provision of war room capabilities for major emergencies.
- The TOC will be a dispatch center for CSP enforcement personnel and CDOT Region 1, 4 and 6 maintenance forces. Communication links to other public safety agencies and jurisdictions will enhance the regional aspect of the TOC and improve incident response capabilities.
- The TOC will communicate with travelers at home, in-vehicle, and at activity centers such as office building lobbies or shopping centers.
- The TOC will provide a location for high technology research in cooperation with local colleges and universities, the Colorado Transportation Institute (CTI), FHWA and other agencies interested in transportation.
- The TOC will support public awareness and education on the purposes, benefits and elements of IVHS in the Denver area.

A summary of various Master Plan activities and their relationship to the TOC is depicted in Figures 3.2 and 3.3. Figure 3.2 shows activities providing input to the TOC, while Figure 3.3 shows activities receiving output from the facility.

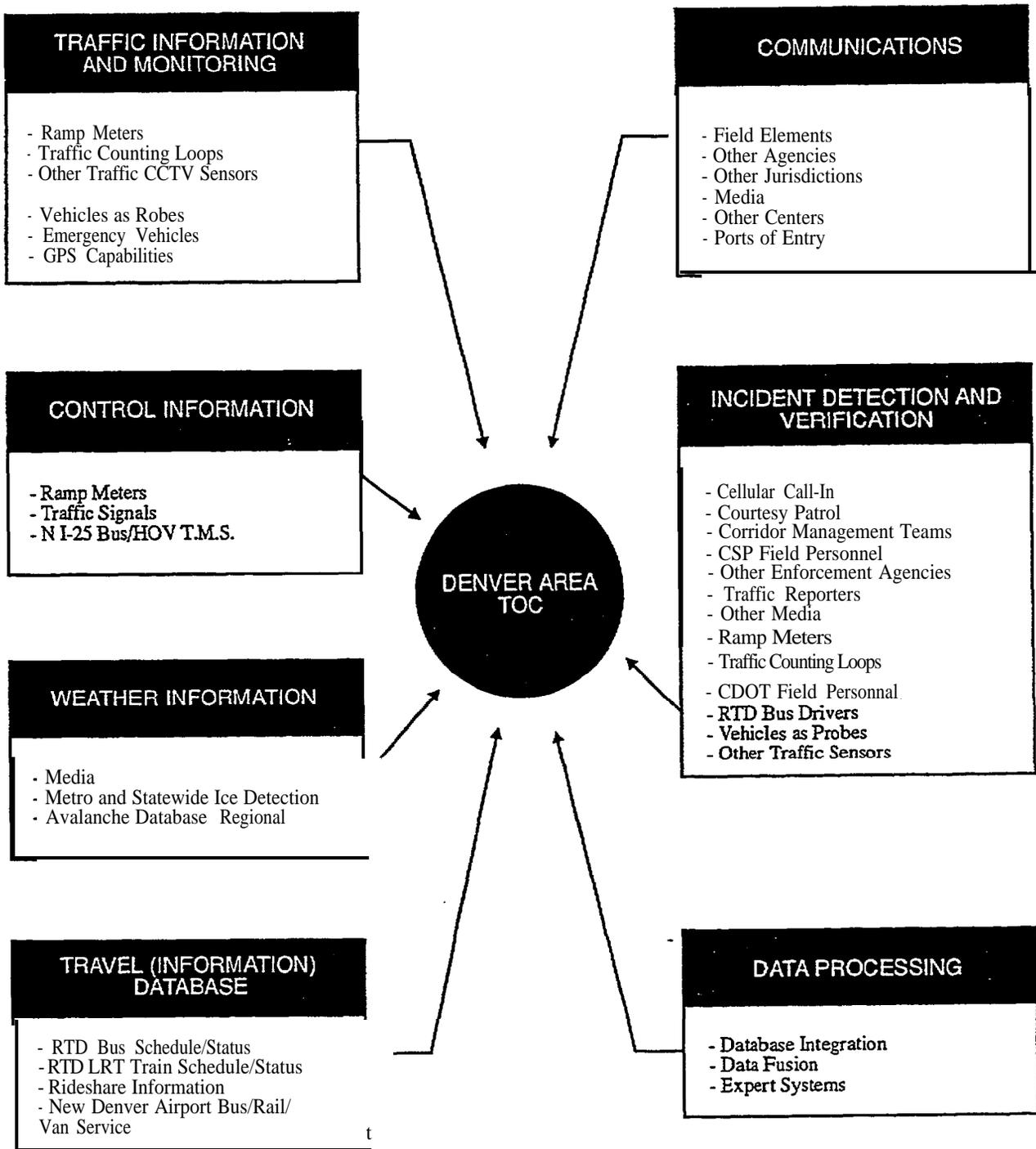


Figure 3.2 Denver Area TOC Inputs

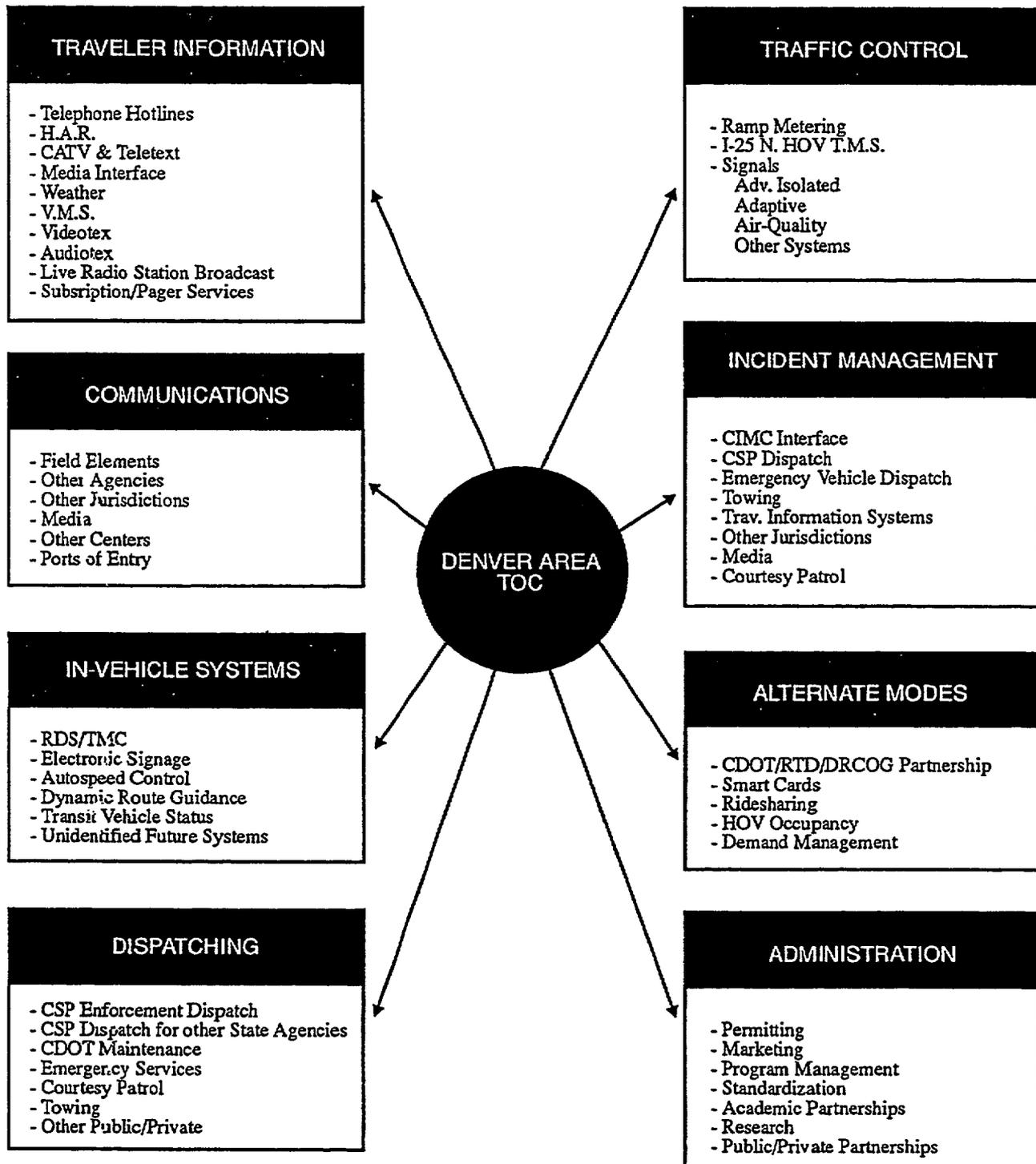


Figure 3.3 Denver Area TOC Outputs

3.6 Regional Impacts of IVHS Activities

This section highlights the impacts of introducing IVHS approaches and technologies throughout the Denver area, addressing the level of influence each activity is expected to produce in the region. These influences can be grouped under a number of global impacts, as follows:

1. Improve safety of transportation.
2. Increase credibility of traffic/travel information.
3. Increase highway capacity, efficiency and travel-time predictability.
4. Enhance personal mobility throughout the Denver area.
5. Improve interjurisdictional cooperation.
6. Respond more rapidly to incidents.
7. Improve intermodal coordination.
8. Reduce environmental and energy impacts.
9. Increase opportunities for public-private partnerships.

Table 3.1 shows both the primary and secondary effects each component IVHS activity is expected to display in terms of technical, institutional and societal impacts. As can be seen from Table 3.1, some activities will display multiple effects of varying degree across the identified impact categories. This graphical depiction is provided to illustrate how IVHS activities can positively influence the Denver area's transportation system.

Table 3.1 - Impacts of IVHS Activities in the Denver Metro Area

IVHS ACTIVITIES	IMPACTS								
	1. Safety	2. Credibility	3. Capacity	4. Mobility	5. Cooperation	6. Incidents	7. Intermodal	8. Environment	9. Public-Priv.
PROVIDE IVHS FOCAL POINT FOR DENVER									
Denver Metro Area TOC	P	P	P	P	P	P	P	P	P
TOC Expert Systems	S	S	P	S	S	P	S	S	
IMPROVE TRAFFIC DATA COLLECTION									
Collection of Real-Time Traffic Information	P	P	P	S		S	P		S
Advanced Arterial Surveillance	S	P	P	S	S	S	S		P
Dial-in Collection System	P	P	S	S		P			
Expanded CCTV Coverage	P	P	S			P		S	
DEVELOP COMPUTERIZED PROCESSING SYSTEMS									
TOC Database Integration	S	P	P	S	S	P	S	S	
TOC Data Fusion	S	P	P	S	S	P	S	S	S
Maintenance Fleet Management Systems	P		S		S	S		P	S
CREATE TRAFFIC RESPONSIVE MONITORING SYSTEM									
Incident Detection and Management	P	S	P	S	P	P	S	S	
TV & Radio Cooperative Exchange System	S	P	S	S		S			P
Public & Private Dispatch	S	S	S		P	P	S		P
Pre-Planned Incident Diversion Routes	P		P	S	P	S		S	
Emergency Service Dispatching & Routing	P				S	P			P
CREATE REGION-WIDE COMMUNICATIONS NETWORK									
Temporary Communications	S	P	P	S	S	P	S	S	P
Permanent Communications	P	P	P	P	P	P	P	P	P

P = Primary
S = Secondary

Table 3.1 - Impacts of IVHS Activities in the Denver Metro Area (continued)

IVHS ACTIVITIES	IMPACTS								
	1. Safety	2. Credibility	3. Capacity	4. Mobility	5. Cooperation	6. Incidents	7. Intermodal	8. Environment	9. Public-Priv.
DISSEMINATE TRAVEL INFORMATION									
Enhanced HAR System	S	P	S				S		
VMS System	S	P	P	S		S		S	
RDS Broadcasting	S	P	S	S		S	S		P
Cable TV & Teletext Information Systems		P	S	S			S		P
Videotex Information Systems		P	S	S			P		P
Audiotex Information Systems		P	S	P			P		S
Dynamic Route Guidance	S	P	P	P		S		S	P
Electronic Signage	P	S	P					S	P
Automatic Speed Control	P	S	P	P				P	P
INTEGRATE TRAFFIC CONTROL SYSTEMS									
Expanded Ramp Metering	S	P	P	S		S	S	P	
Isolated Intersection Control			P					P	S
Reversible Lanes			P	S	S	S		S	
Adaptive Traffic Control		S	P	S	S	S		S	S
Air-Quality-Responsive Traffic Control			P		P			P	S
4th Generation Signal Control	S	S	P	P	P	S		S	S
ENHANCE ALTERNATIVE MODES OF TRAVEL									
Interactive Rideshare Matching System		S	P	P			P	P	
HOV Occupancy Verification			P	S			S	S	S
Integrated Demand Management			P	S	S		P	S	
Smart Cards			S	S	S		P		
Transit Vehicle Status Monitoring	S	S		S			P	S	
CDOT/RTD/DRCOG Partnership		P	P	S	P	S	P	S	

P = Primary
S = Secondary

4. ACTIVITY COORDINATION

4.1 Introduction

The previous chapter outlined a systematic process for the deployment of IVHS-based initiatives in the Denver area. This chapter examines current activities in Denver and Colorado that could contribute to the success of IVHS in the Denver area. These other state IVHS projects, as well as national initiatives, will be coordinated with this effort to ensure that IVHS is implemented in a consistent, logical and incremental fashion

The development of strong ties with other existing and planned activities should ease the integration and implementation of proposed Master Plan projects. It should also create cost-efficiencies associated with infrastructure deployment. This chapter discusses opportunities for coordination of the Master Plan activities with current regional activities, statewide initiatives and national efforts.

4.2 Current Regional Programs

4.2.1 Introduction

Some of the initial IVHS efforts in the region will focus on incorporating systems and activities that are already operating in the Denver area. CDOT, DRCOG, CSP, RTD, CIMC, and local city and county governments have implemented a number of demand management techniques, traffic management initiatives and incident response plans to address the Denver region's transportation challenges.

The following sections outline existing systems in the Denver area and explain how they will be integrated with IVHS and the regional TOC. This will include system upgrades and enhancements, and integration with other IVHS-related services. The challenge is to develop a coordination framework which will combine and integrate these efforts in a single, focused agenda.

4.2.2 Ramp Metering

CDOT monitors and operates a network of freeway ramp meters at 28 locations, primarily situated in the east and south portions of the Denver area along I-25 and I-225. The existing ramp meter locations, their specific times of operation and type of ramp metering control are summarized in Table 4.1. The typical CDOT installation is capable of providing both isolated traffic responsive metering as well as further, integrated operations as part of a regionwide system (Reference 5).

CDOT is currently in the process of expanding this freeway ramp metering system at a number of locations throughout the Denver region. At these locations, the most traffic disruptive work element, that of installing inductive loops in the pavement, has already been completed. Table 4.2 identifies areas where this work has been undertaken. Figure 4.1 graphically illustrates both the existing ramp metering locations as well as those locations which possess count detector installations.

Table 4.1 - Existing Entrance Ramp Meter Installations

Location	On-Ramp	Hours of Operation	Type
I-25 at Colorado Blvd.	NB 1	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
	NB 2	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM, HOV
I-25 at Evans Ave.	NB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
I-25 at Yale Ave.	NB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
I-25 at Hampden Ave.	NB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM, HOV
I-25 at Belleview Ave.	NB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM, HOV
I-25 at Orchard Rd.	NB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
I-25 at Arapahoe Rd.	NB 1	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM, HOV
	NB 2	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM, HOV
I-25 at Dry Creek	NB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
I-25 at County Line Rd.	NB 1	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
	NB 2	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
I-225 at Colfax Ave.	NB	7:00 a.m. to 10:00 a.m.	ITRM
	SB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
I-225 at 6 th Ave.	NB	7:00 a.m. to 10:00 a.m.	ITRM
	SB 1	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
	SB 2	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM

TRM - Traffic Responsive Entrance Ramp Metering

ITRM - Integrated Traffic Responsive Entrance Ramp Metering

HOV - HOV By-Pass of Metering

Table 4.1 - Existing Entrance Ramp Meter Installations (continued)

Location	On-Ramp	Hours of Operation	Type
I-225 at Mississippi	NB	7:00 a.m. to 10:00 a.m.	ITRM
	SB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
I-225 at Iliff Ave.	NB	7:00 a.m. to 10:00 a.m.	ITRM
	SB	7:00 a.m. to 10:00 a.m.	ITRM
I-225 at Parker Rd.	NB	7:00 a.m. to 10:00 a.m. 3:30 p.m. to 6:30 p.m.	ITRM
	SB	7:00 a.m. to 10:00 a.m.	ITRM, HOV
I-225 at Tamarac Pkwy.	SB	7:00 a.m. to 10:00 a.m.	ITRM
I-270 at York St.	SB		ITRM
I-70 at Peoria St.	WB		IRTM
I-70 at Havana St.	WB		ITRM
US 6 at Federal Blvd.	WB		ITRM

TRM - Traffic Responsive Entrance Ramp Metering

ITRM - Integrated Traffic Responsive Entrance Ramp Metering

HOV - HOV By-Pass of Metering

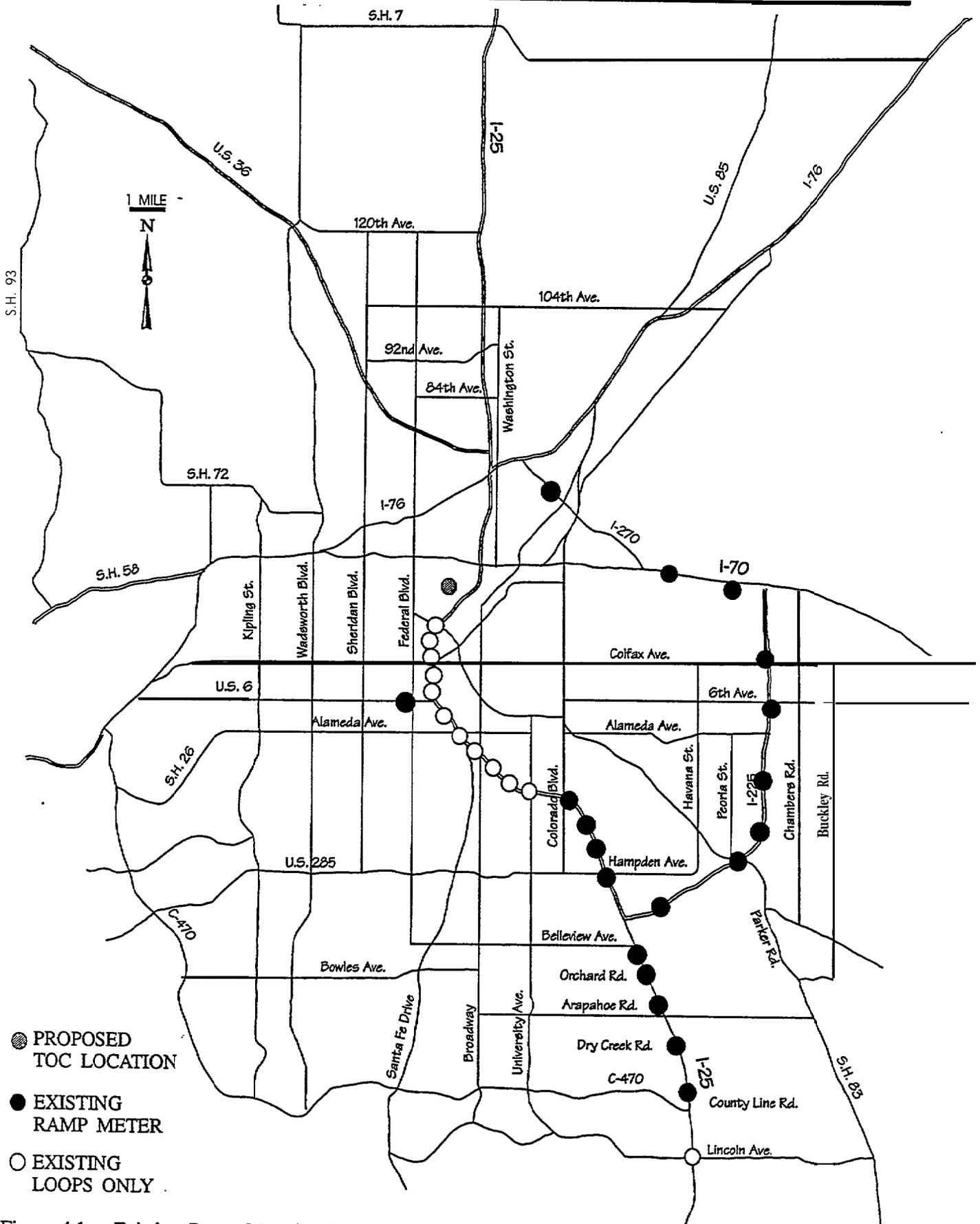


Figure 4.1 Existing Ramp Metering Locations and Count Detector Installations

Table 4.2 - Existing Count/Speed Detector Locations

Freeway	Interchange	Loops
I-25	Speer Blvd.	SB1,SB2
	23 rd Ave.	NB,SB
	19 th Ave.	SB
	17 th Ave.	NB
	Auraria Pkwy.	NB
	Colfax Ave.	SB
	8 th Ave.	NB
	8 th Ave./Zuni St.	SB
	6 th Ave.	NB,SB
	Alameda Ave.	NB
	Santa Fe Dr.	SB
	Broadway	NB,SB
	Washington	NB,SB
	University Ave.	NB,SB
	Colorado Blvd.	SB
Lincoln Ave.	NB	

CDOT will be upgrading the ramp metering computer system in the near future to obtain greater control and monitoring flexibility over both the existing network and future installations. Improved software will provide graphical displays of freeway conditions throughout the system. It is anticipated that the central computer controlling the ramp metering system will be relocated from the CDOT Region 6 building to the Denver TOC.

The ramp metering detector installations have the potential to provide valuable input to the development of the Denver area's automatic incident detection algorithms. In addition, the existing loop detection installations, shown in Table 4.2, can be used as real-time traffic volume, speed and occupancy count stations prior to implementation as ramp metering sites. These sites are considered key locations for direct communications with the Denver TOC.

4.2.3 Environmental sensor systems

The Denver Area freeways include a network of CDOT environmental sensor systems (ESS). There are currently eleven monitoring stations with about 70 surface sensors used to detect and predict the formation of ice on the roadway (Reference 6). The locations of the current installations are listed below and graphically displayed in Figure 4.2:

- . I-25 at 120th Avenue.
- . I-25 at U.S. 36.
- . I-25 at I-70.
- . I-25 at Colfax Avenue.
- . I-25 at Santa Fe Drive.
- . I-25 at C-470.
- . I-70 at C-470.
- . I-70 at I-225.
- . C-470 at Wadsworth Boulevard.
- . Federal Boulevard at Alameda Avenue.
- . Colfax Avenue at Colorado Boulevard.

In addition to these Metro Area ESS, numerous systems exist throughout rural Colorado.

CDOT is participating in a research project funded by the FHWA involving the development of new ESS. As part of this project, evaluations of the operation of the existing ESS will be used to develop prototype advanced sensor technology. At present, the advanced sensor technology is foreseen to include potential improvements in the areas of visibility monitoring, precipitation intensity, pavement chemical concentration and wind force.

In the early stages of the Denver area IVHS program, communications between ESS locations and the Denver area TOC should be established. The TOC will then integrate weather-related data to assist both CSP and CDOT maintenance dispatching as well as interfacing the ESS with the appropriate ATIS services. In the future, all of Colorado's ESS are planned to be monitored by a single computer system, potentially located at or connected to the Denver TOC.

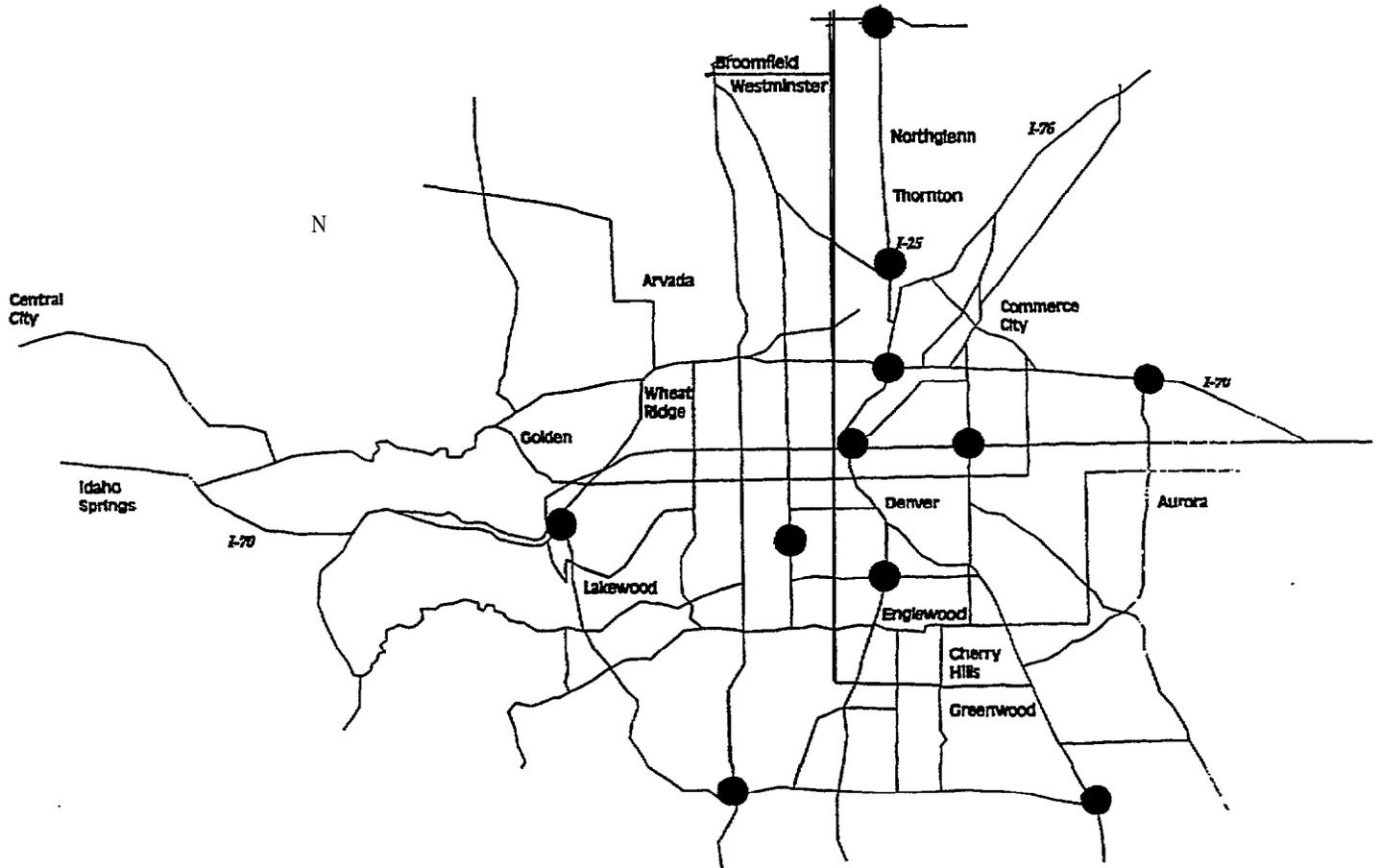


Figure 4.2 Denver Metro Area Environmental Sensors

4.2.4 Telephone hotlines

CDOT currently maintains three telephone hotlines which provide weather, roadway and construction information to Colorado's motoring public. One is for statewide roadway conditions (639-1234); another is for roads within two hours of Denver (639-1111); and the third is for construction activities in the north I-25 corridor (573-ROAD).

CDOT has reported that several complaints have been received concerning the existing system. These include out-of-date travel information, undiscernible taped messages and long delays caused by the limited number of telephone lines in to the system. In addition, US West may not allow CDOT continued use of the 639 exchange.

In light of these problems, criteria for improving the telephone system need to be established. Using IVHS approaches, the hot line system has the potential to be updated into a menu-driven, touchtone traveler information service. Message generation would take place at the TOC, thereby providing real-time traveler information and automatic updating capabilities. Housing this system at the TOC would also allow the caller to be connected to a TOC operator under emergency conditions. An increase in the number of phone lines may additionally be considered, perhaps with the use of private sponsorship to offset operating costs.

4.2.5 Highway Advisory Radio (HAR)

There are currently eight permanent low-power HAR installations on interstate freeways around the Denver Area (Reference 6). These are displayed in Figure 4.3 and listed on the following page.

- 1) I-25 (north of 120th Avenue).
- 2) U.S. Highway 36.
- 3) I-76.
- 4) I-70 (east of Buckley Road).
- 5) I-70 (west of C-470).
- 6) I-25 (south of C-470).
- 7) Stapleton International Airport.
- 8) Cherry Creek Reservoir Recreation (CCRR).

With the exception of Stapleton and Cherry Creek, operation and maintenance responsibilities for these HAR installations lie with CDOT. In addition, CDOT has plans to install four more HAR systems in the Metro Area. When airport operations are transferred from Stapleton to the new Denver International Airport, these four additional transmitters will cover the central portions of I-25 and I-70. Beyond this physical expansion, further HAR installations on all freeways and significant arterials could be prioritized by degree of congestion experienced on the roadway.

HAR provides the motoring public with information on construction activities and road closures. The potential exists for HAR to be integrated with the Denver TOC's real-time

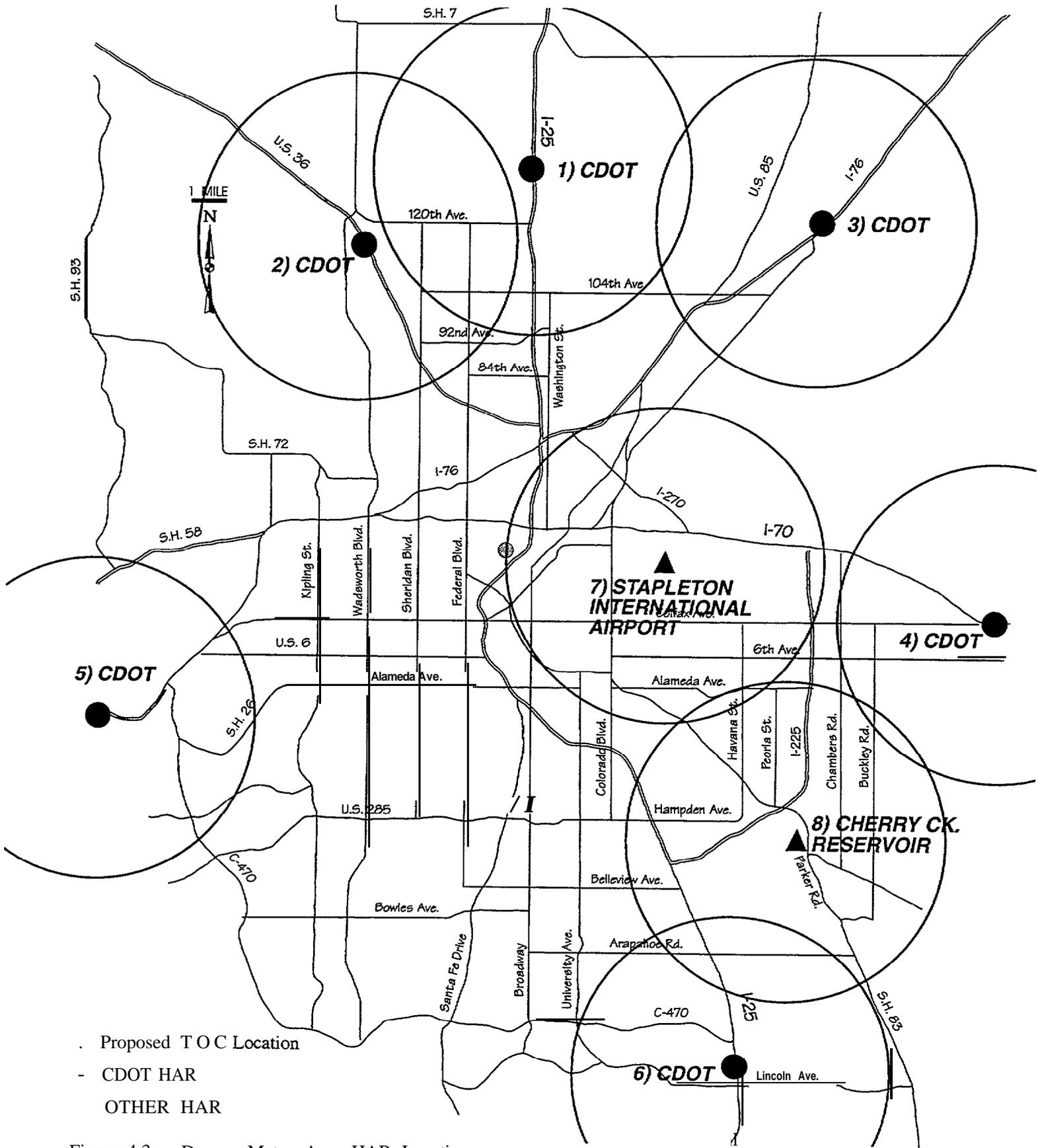


Figure 4.3 Denver Metro Area HAR Locations

message generation capabilities. This would provide more reliable information and up-to-the-minute traffic reports.

4.2.6 North I-25 Traffic Management System (TMS)

CDOT, RTD, and the City and County of Denver (CCD) are cooperatively developing a two-lane reversible bus and high occupancy vehicle (HOV) facility in the north I-25 corridor between 70th Avenue and 20th Street (Reference 7). When completed, the bus/HOV facility will include a state-of-the-art traffic management system with lane and gate control, variable message signs (VMS), an extensive network of loop detectors, closed circuit television CCTV monitoring and computer-aided command and control capabilities. CDOT will be responsible for the control of this system and is expected to incorporate operations into the Denver TOC.

The North I-25 TMS program provides significant opportunities to support the overall IVHS initiative. The loop detector network provides the foundation for real-time traffic information collection as the basis for ATIS and ATMS ventures. The deployment of VMS and CCTV systems on I-25 will contribute to the creation of regionwide traffic monitoring and control capabilities. The North I-25 TMS will also serve as the initial leg of Denver's communications network. Additional IVHS systems and technologies, such as HOV occupancy verification, could be deployed within this corridor to complement the existing IVHS infrastructure.

4.2.7 CIMC Initiatives

The CIMC is actively pursuing opportunities in the area of incident management programs. The group published a recommendations report in September, 1992, which identified over 26 actions to be taken in the next few years to improve the Denver area's incident management capabilities (Reference 8). Many of these are reflected in the IVHS Master Plan. This will ensure consistency between the CIMC effort and the overall Denver area IVHS initiative.

The key to implementation of these incident management programs is the assumption of responsibility by appropriate agencies for their day-to-day coordination and management. This must include true commitment, in terms of staff and resources, to put the recommendations into practice. The Denver TOC, preplanned incident diversion routes, enhanced HAR system and expanded CCTV coverage are examples of the CIMC/IVHS overlap activities. Specific implementation and coordination details are provided in both the CIMC Final Report and the individual activity descriptions in Appendix A.

4.2.8 RTD Global Positioning System (GPS)

RTD has implemented a GPS-based automatic vehicle location (AVL) and computer-aided dispatch tool for its transit fleet (Reference 9). Implementation of the GPS system greatly enhances RTD's fleet management capabilities, and also provides the foundation for advanced information services such as audiotex. In addition, RTD's GPS system could be expanded to incorporate CDOT maintenance fleet management, in an effort to create cost efficiencies and promote the evolving CDOT/RTD/DRCOG partnership. The upcoming IVHS demonstration tests described earlier in this document will rely heavily upon the GPS/AVL system to provide real time transit information.

RTD's dispatch center could be electronically linked to the Denver TOC. This would allow the TOC to operate multi-modal ATIS services. An RTD/TOC interface would also introduce the ability to use the transit fleet as probe vehicles. The probe vehicle concept would supply valuable real-time traffic flow information and additional incident detection sources, in support of the TOC's ATIS and ATMS efforts.

4.2.9 Demand Management

DRCOG and RTD jointly offer a number of alternative transportation services which include employer incentive arrangements to promote transit, assistance in the formation of carpools and vanpools, and a guaranteed ride home program. These conventional demand management approaches can be combined with evolving transit technology, such as the North I-25 HOV Lane, as well as with new technologies such as HOV occupancy monitoring, to enhance mobility by reducing capacity overload in the Denver area.

IVHS seeks to build on these current activities and promote use of efficient transportation modes. For example, one potential activity might be a real-time rideshare matching system which the public could access over the telephone. Such a system could be housed within DRCOG's Ride Arrangers Program and integrated with the Denver area TOC. Incorporating integrated demand management strategies within the Denver TOC should aim not only to enhance the multi-modal aspects of IVHS, but also to promote a publicly acceptable approach to congestion reduction in the region.

4.2.10 Regional Signal Coordination

DRCOG currently coordinates a regional traffic signal system improvement program to implement traffic signal timing and coordination projects within the Denver area (Reference 11) and to improve traffic signal coordination across jurisdictional boundaries. These efforts will be enhanced in the future by the continued implementation of communication systems along regional arterials and may eventually be further enhanced by the application of advanced traffic control systems. These systems could be electronically linked to the Denver TOC to support freeway and arterial coordination when incident diversion routing is required, and to provide link travel-time information for dynamic route guidance systems.

It is believed that the Denver area transportation system could function more efficiently through interaction between the different signal control systems currently operating on the arterial street network. Since these signalized arterials are maintained by various local jurisdictions, their cooperation and DRCOG's continued guidance will be central to the success of Denver area advanced traffic control strategies. Early involvement of these jurisdictions in demonstration projects could help to establish their support, as well as providing operational improvements such as reduced delays and vehicle emissions. DRCOG would seem the natural agency to continue to lead these efforts, and could also establish guidelines for further coordination with the Denver TOC.

4.3 Statewide Initiatives

4.3.1 Introduction

Colorado is actively pursuing a number of IVHS projects and opportunities. IVHS technologies are seen as a movement toward the state's vision of a highway system offering increased efficiency and safety, enhanced support for commerce and public-private partnerships, overall transportation coordination, and reduced environmental impacts.

In Colorado, IVHS activities will be pursued within the framework of the state's C-Star Strategic Plan. Components include the I-70 Corridor Study and ENTERPRISE, in addition to the Denver area IVHS initiative. This section recognizes the need for coordination of the Denver area's efforts with those of other statewide IVHS activities.

4.3.2 C-Star Program

The C-Star program represents a statewide strategy for the research, development, demonstration and deployment of IVHS technologies in Colorado. C-Star provides an integrated plan for combining ongoing efforts with new initiatives (Reference 6).

A key component of the C-Star program is the establishment of a system of interconnected IVHS centers that will control regional transportation operations throughout Colorado. Initial operational centers for IVHS will build on existing facilities such as the Eisenhower/Johnson Memorial tunnel control center (TCC) and Hanging Lake TCC in Glenwood Canyon. The Denver area TOC will also act as a regional IVHS operations center, and is expected to serve as the central coordinating facility for the entire state.

In moving toward realization of this network of IVHS operations centers, a first step will be to interconnect the Denver TOC with the two major TCCs. This will allow traveler information and traffic management data to be passed from one facility to the next as vehicles move along the highway. This concept is analogous to air traffic control operations.

The implementation of communications channels between the two TCCs and the Denver TOC is important since all three facilities will ultimately form part of an interconnected traffic operations network. A significant opportunity lies in the potential for use of the statewide microwave communications network. This can accommodate large volumes of information and has the ability to support many IVHS-related data transfer applications. The Hanging Lake facility is already linked into this system, while microwave connections for the Eisenhower/Johnson TCC are being pursued by the State Division of Telecommunications. Connections with these centers are also being considered in the TOC design process.

Proceeding in parallel with these efforts, a further component of the C-Star agenda involves instrumentation of Colorado's highway network with ATMS data collection mechanisms, including environmental sensors. Statewide deployment of these systems will be coordinated with local initiatives to ensure program compatibility and consistency. The placement of these data collection sources throughout Colorado will allow the Denver

TOC to exchange information with other regional operating facilities in support of statewide ATIS services.

4.3.3 I-70 Corridor Study

This study is investigating the characteristics and problems of the I-70 corridor, identifying those areas that are most applicable to IVHS solutions. The project, recently initiated by CDOT, is focusing primarily on the needs imposed by weather conditions and traffic demands, through consideration of traffic management and traveler information approaches.

Like the Denver IVHS program, the I-70 initiative is expected to lead to recommendations for phased deployment of IVHS technologies. The I-70 corridor's IVHS elements could include a data collection and surveillance network, and increased use of VMS and environmental sensor systems, among others. Deployment of equipment along I-70 could learn from or provide guidance to similar efforts in the Denver area, depending on when installation occurs.

In addition, since both the Eisenhower/Johnson TCC and the Hanging Lakes TCC are located along the corridor, the I-70 study will address their potential roles in supporting and controlling IVHS approaches. This will include consideration of the scope for interfacing the TCCs with the Denver TOC, in line with the C-Star plan outlined above.

4.3.4 ENTERPRISE

The ENTERPRISE program is a multi-state initiative aiming to facilitate rapid progress in the development and deployment of IVHS technologies. Colorado is a lead member of ENTERPRISE, with responsibility for administering the program. An offshoot of CDOT's participation in the ENTERPRISE program was the development of Colorado's statewide strategic IVHS plan, C-Star.

More recently, ENTERPRISE has shifted from an initial planning phase to selecting research and development projects for group funding. ENTERPRISE has already undertaken a strategic location coding study to provide geographic referencing for digital ATIS technologies. This will provide a platform for ATIS ventures such as digital radio broadcasting in the Denver area.

Colorado's involvement in the ENTERPRISE program has the potential to be extremely beneficial for the Denver area. Through ENTERPRISE, the local IVHS program will learn from the experiences of other states and metropolitan areas with similar needs and interests. In addition, ENTERPRISE offers a mechanism to initiate joint technical projects with cost-sharing benefits for all involved agencies. Some of the Denver Area Master Plan projects may therefore be considered for ENTERPRISE support

4.3.5 Operational Tests

CDOT envisions that its IVHS efforts must address existing systems as well as anticipate future opportunities. These include Research and Operational Tests to encourage and provide facilities for leading-edge research and development and operational tests of state-of-the-art technology. CDOT has create the Colorado Transportation Institute (CTI) to foster transportation research. Colorado is also the lead state for the ENTERPRISE

program which was established as an international forum for collaborative research, development, and deployment ventures in IVHS. The forum is intended to facilitate the sharing of technological and institutional experiences gained from the IVHS programs conceived and initiated by each participating entity. In addition, CDOT currently is undertaking the following projects:

- *I-70 Hogback multi-modal transfer facility* - This FHWA demonstration project will focus on utilizing the parking lots at the Morrison Road exit to I-70 to promote both carpooling and transit. It involves CDOT, RTD, Jefferson County and the gaming interests in Black Hawk and Central City. Additional partners are being sought for both initial and future phases.
- *Dynamic truck speed warning system for long downgrades* - This FHWA demonstration project is designed to improve truck safety on long downgrades. Located on the west side of the Eisenhower Tunnel on I-70, it will combine weigh-in-motion technology with variable message signs to tell truckers of safe operating speeds. International Road Dynamics, Inc. is a partner on this project and will be supplying equipment and software.
- *RTD real time transit information projects* - RTD, in partnership with CDOT and Westinghouse Electric Corporation, was selected by USDOT to demonstrate the feasibility of providing real time transit information and to assess the influences of such information on the traveling public. The first element will provide real time information from RTD's GPS/AVL system on television monitors placed at selected transit centers, park-n-Rides, and at DIA. Real time arrival and departure information will be displayed, similar to the information shown on airport screens. The second element will evaluate whether enhanced transit information will increase ridership. The second element will be evaluated through the EcoPass ridership program.
- *I-70 Rural IVHS study* - CDOT has recently initiated a feasibility study of implementing IVHS technology along the I-70 corridor between Denver and Glenwood Spring. There will be close coordination with the many agencies, local governments, and interested citizens along this corridor. One task of the consultant on this project involves identifying potential private partners along the corridor.
- *CamReal* - CDOT is participating in multi-state planning effort to define the transportation impacts which could result from implementation of the North American Free Trade Agreement (NAFTA) between the U.S., Canada, and Mexico.
- *HELP* - The Heavy Vehicle Electronic License Plate (HELP) Program is a multi-state developmental research effort to design and test a integrated heavy vehicle monitoring and management system. HELP includes the Crescent Demonstration Project which is field testing Automatic Vehicle Identification (AVI), Weigh-in-Motion (WIM), and Automatic Vehicle Classification (ACS) technology which is electronically linked via a computerized data communications system. In addition to the many states involved, HELP is supported by a number of independent trucking companies. HELP has formed a non-profit organization to foster partnerships. Colorado implemented its first electronic port of entry on Raton Pass near Trinidad in 1993.

- **COVE**- CDOT is the lead of a six state consortium which will study commercial vehicle operations (CVO) and institutional barriers. The goal is to create “transparent borders” for commercial vehicles utilizing electronic technology and IVHS concepts. The trucking industry is an active participant in this study.

4.4 National IVHS Efforts

4.4.1 Introduction

As IVHS technologies and systems are introduced in the United States, efforts to establish a national vision of the future transportation system are underway. Several major groups are contributing to the overall United States IVHS program. This section of the Master Plan outlines the need for coordination of Denver’s IVHS activities with these national initiatives, specifically in the areas of standardization and funding.

4.4.2 Standardization

IVHS represents a new way of thinking for the United States in the area of highway transportation. It aims to apply computers, communications and other advanced technologies in addressing the surface transportation system’s current and future needs. In order to promote widespread consistency and the most efficient IVHS designs, efforts to develop technical and operational standards are being pursued (Reference 4).

FHWA recognizes these needs and is sponsoring several programs aimed at developing standards in critical IVHS areas. While it is not recommended that Denver delay its program until completion of these Federal efforts, care should be taken to ensure that the region does not get locked into systems that may be incompatible with the ultimate Federal standards.

For example, FHWA is currently working to develop a nationwide systems architecture for use in IVHS systems, specifically TOCs. This effort, and other related activities, will lead the progression toward U.S. DOT’s vision of an automated highway system (AHS). The intent of such standardization is to develop IVHS system structures which make sense on a national level. Among the issues being discussed include architectures for radio communications, CCTV, and fiber optic trunk communications, as well as non-proprietary systems, interchangeability of components, common communications interfaces between computer systems, and similar issues. Work is currently proceeding at great speed, but may not be 100% completed prior to the time when the Denver area moves forward to final design of the TOC. To address this issue, Denver’s approach to IVHS, specifically the TOC, should reflect a flexible, modular and open system configuration. To the extent possible, all software, equipment and systems deployed should be non-proprietary. The Denver area should utilize system architecture recommendations as they are developed and released by FHWA.

The Denver area’s congestion and air quality problems demand action. However, it must be recognized that future IVHS standard setting may necessitate some changes to the initial system deployed in the Denver area. One key factor in minimizing the difficulties inherent in system modifications or upgrades is the standardization of system operating parameters and interfaces. This provides the capability to change various modules of a

system without having to replace or adjust other components at the same time. Use of this type of modular approach will also support compatibility with new products and services in the future, as well as integration of the Denver area's system with other IVHS components in Colorado, and ultimately as part of a national IVHS network.

Although realization of AHS is a long-term initiative, it will introduce such significant changes to our transportation system that planning for automated driving should begin now. Like other major metropolitan areas, Denver will be a target for future AHS deployment. Current activities should therefore be undertaken with this consideration in mind.

The Master Plan's recommended IVHS efforts for the Denver area will promote the ultimate realization of AHS in two primary ways. First, initial IVHS equipment deployments in the region should be capable of supporting progressive introduction of AVCS approaches. For example, collection of real-time data could lead to roadside speed advisories, followed by in-vehicle messages, and finally automatic speed adjustment. Second, the resident population of the Denver area will be exposed to IVHS and its benefits through a series of incremental steps. This will allow the movement toward AHS to occur as a smooth progression, rather than as a sudden radical change in the region's transportation system.

4.4.3 Federal Funding Opportunities

Federal money is always a popular choice for funding new transportation systems. However, Federal funds can be difficult to obtain, precisely because they are so much in demand. Nonetheless, Federal support for IVHS may be crucial in order to provide consistency in different areas, technical guidance, national exposure to important technologies, and large-scale funding for major initiatives such as future AHS deployment.

The majority of Federal funding for IVHS initiatives in the U.S. can be traced back to the 1991 Intennodal Surface Transportation Efficiency Act (ISTEA). In 1993, ISTEA provisions included \$113 million specifically for IVHS activities. An additional \$30 million for IVHS was provided by the U.S. DOT Appropriations Act.

Continued support for current IVHS initiatives, as well as proposed funding increases for the Federal IVHS program, were unveiled as part of the Clinton Administration's economic plan. For fiscal years 1994 through 1997, the plan calls for a total of \$925 million in IVHS funding. Table 4.3 provides a breakdown of the Clinton Administration's IVHS funding plan.

As can be seen from Table 4.3, the existing \$113 million in ISTEA authorizations are being continued. In addition, the "current services baseline" funds are intended to maintain the level of funding support that the IVHS program currently receives. The figures for the next four years reflect inflation adjustments to the \$30 million appropriated by U.S. DOT for IVHS. The real increases in IVHS funding from the Clinton-led DOT are represented in the Rebuild America program, which includes \$345 million in so-called "smart cars/smart highways" funding over the next four years.

**Table 4.3 Clinton Administration’s Proposed IVHS Funding
FY94-97 (In \$ Millions)**

	FY94	FY95	FY96	FY97	Total
Rebuild America Funds	70.00	85.00	90.00	100.00	345.00
Current Services Baseline	30.81	31.61	32.40	33.21	128.03
Existing ISTEA Authorizations	113.00	113.00	113.00	113.00	452.00
TOTALS	213.81	229.61	235.40	246.21	925.03

Source: Federal Highway Administration

Clearly, then, there are significant Federal funds available for IVHS projects. However, in accordance with the U.S. National Transportation Policy, much of this funding is contingent upon the establishment of partnerships between Federal, state and local governments and private industry to share both the financial and management responsibilities. In addition, U.S. DOT has already established a policy for funding IVHS operational tests. This states that a maximum of 50 percent of project funds can be provided by Federal monies through ISTEA. An additional 30 percent of costs can be met from other Federal funding sources, for example, state planning and research funds. The remaining 20 percent must be a non-Federal “hard” match. This can reflect state or local funds or, preferably, private sector contributions

Against this background, it is expected that an important part of the Denver IVHS program will be the development of requests for Federal IVHS funding. FHWA’s operational test program is seen as a particular area of opportunity. Here, FHWA plans to announce its interests with respect to IVHS operational tests on a regular basis. Where these interests match with planned activities in the Denver area, Federal funding requests can be pursued. Projects which are considered potential candidates for IVHS operational tests are identified in Appendix A.

The development of IVHS funding proposals to the Federal government requires an awareness and detailed understanding of both the written and unwritten approval criteria. Specific criteria and issues to be addressed in funding requests include:

- A demonstrated contribution to the national goals of IVHS and consistency with the strategic plans of U.S. DOT and IVHS America.

- A clear demonstration of multi-institutional and multi-jurisdictional cooperation and willingness to deploy seamless systems.
- If at all possible, the project should involve a partnership with the private sector whereby the private partners contribute financially to the project. In any case, the Federal government will not support a project where the primary benefit lies in the area of private sector responsibility.
- The project should be shown to be an integral part of ongoing transportation management programs.
- If operational test monies are sought, the project must demonstrate that it is advancing the technological state-of-the-art or is obviously distinguishable from other projects or programs.
- It is critical that the required twenty percent of nonFederal funds to be contributed to the project be firmly committed and clearly accounted for in the project proposal.
- IVHS funding of any kind will only be provided when an activity or task is not eligible for other forms of Federal aid.

5. SUMMARY

5.1 Introduction

This document has discussed the application of IVHS technologies in the Denver area, represents the overall Master Plan, and should be considered a tool in the regional struggle to overcome increasing traffic congestion. As the cornerstone of the Denver area IVHS Study, this Master Plan outlines research, development, demonstration and deployment activities applicable to the region. It builds on and integrates the projects recommended in the Strategic Plan and Early Action Plan, providing greater detail for each activity in terms of scope of work, approach, organization, funding and other important issues. This chapter reviews the content of the document and draws some overall conclusions on IVHS implementation in the Denver area.

5.2 Master Plan Overview

Chapter 1 provided a brief overview of the Denver area IVHS Study. It explained the purpose of the Master Plan in the study and presented snapshots of the Denver area under future (short-, medium-, and long-term) IVHS scenarios.

Chapter 2 discussed the overall goals of the Master Plan and the implementation of IVHS in the Denver area. Achievement of the nine key objectives will help provide the region with a more efficient and effective highway network, expedient and coordinated incident response capabilities, reduced accident and fatality rates, increased highway safety and minimized impacts of adverse environmental conditions. Finally, true public-private partnerships will be achieved, promoting enterprise and innovation, and supporting the local economy.

Chapter 3 provided a descriptive picture of the way IVHS could develop in the Denver area, and summarized activities that could take place in a phased implementation program. It explained how existing systems will be incorporated into the program and provided charts and figures which offered a visual explanation of the initiative. The chapter also addressed the relationships, timing and impacts of the activities within the Denver area,

Chapter 4 examined current local and statewide activities that could contribute to IVHS in the Denver area. These other Colorado IVHS projects, as well as national initiatives, will be coordinated with this effort to ensure that a consistent, logical and incremental program develops within the appropriate framework.

The culmination of this document's efforts is presented in Appendix A. This appendix provides a detailed summary of each component IVHS activity within the overall Master Plan. It outlines a possible approach for each project in terms of scope of work, organization and funding. These detailed project descriptions will serve as guidelines from which to pursue individual IVHS activities.

5.3 IVHS Development

IVHS in the Denver area will need to continue beyond this Master Plan and its related IVHS Study documents. As technologies mature, future work requirements associated with the overall implementation effort will maintain the momentum of the initiative while moving it forward in a coordinated manner. These requirements involve organization, activity prioritization and funding.

5.3.2 Organization

A variety of organizations could contribute to coordination and management of the Denver area's IVHS efforts. These include state and Federal agencies, local jurisdictions, academia and the private sector. Involvement of multiple organizations will promote consensus and representation, helping to move IVHS in Denver forward in a timely and efficient manner.

CDOT is currently modifying its organizational structure to better implement IVHS. Central to these efforts will be mechanisms to generate consensus and support for IVHS activities as well as to determine priorities, project management, solicitation of funding, and outreach efforts.

5.3.2 Activity Selection

In order to move forward from the current IVHS Study, various CDOT representatives will need to be charged with specific early action responsibilities. One of the most important tasks covers the selection of IVHS activities for initial implementation in the Denver area.

This Master Plan presents a series of IVHS activities and outlines the level of effort required for each one. These activities have been grouped under a number of global objectives and set within a general phased implementation program. In addition, selected activities have been identified as early priorities and included in the Early Action Plan.

These guidelines should assist in the process of prioritizing projects and selecting the first projects to be undertaken. However, the final decision should be made by the organizations that will undertake the IVHS implementation efforts. Therefore, CDOT and the other affected agencies should examine recommended activities in the light of local requirements and funding availability, and determine which projects they wish to pursue as initial IVHS elements.

5.3.3 Funding

Each activity description in Appendix A contains information highlighting the expected funding approach for the project. This includes an assessment of resource requirements for program activities and potential funding sources. **The figures are intended to be used for estimating purposes for individual projects and should NOT be considered an overall budget or funding request for implementation of IVHS in Denver.** As mentioned several times throughout this document, funding limitations will preclude the implementation of many of the listed activities.

CDOT does not anticipate pursuing all of the projects detailed in Appendix A, and many of these will not develop without a public private partnership to help distribute costs. For example, the overall totals for all of the Appendix A projects during all planning periods is about \$280 million, of which approximately 70% is for the “full build out” communications system (if the low priority segments are deleted from the Communications Plan, the overall total drops to about \$200 million), an amount which could not possibly be borne by CDOT or the other public agencies mentioned in this document. As a consequence, to help further tie down IVHS implementation strategies, CDOT is currently developing an IVHS “Business Plan” with more specific timetables and consideration of these financial restraints.

Once activities have been selected, funding will need to be secured to support their implementation. Three primary categories of funding are appropriate for activities in the Denver IVHS program. These are public funds, private funds, and public-private cooperation.

Public financing (state, Federal and local) is most applicable where costs are associated with infrastructure improvement. Public financing may be obtained locally through taxation and specific user fees. In addition, the 1991 ISTEA has dedicated significant public funds to IVHS.

Private sector funding is more appropriate for systems associated with individual motorists and vehicles. The potential to develop new, commercially-available IVHS products for the consumer market in Denver should prove attractive to the private sector,

Public-private cooperation and joint IVHS funding is currently in use in several North American IVHS ventures. This approach supports the entry of private sector firms into technical areas which may be considered too high-risk for full private investment. It is considered particularly appropriate for projects which seek partial Federal funding through FHWA’s operational test program.

5.3 Concluding Remarks

IVHS approaches have great potential as tools to make a major contribution to highway efficiency, safety and the environment in the Denver area. This Master Plan and its associated IVHS Study documents provide a platform for the realization of these benefits. The challenge is now to pursue IVHS implementation through targeted IVHS activities within a phased deployment initiative.

The focal point for IVHS in the Denver area will be the TOC. However, this facility will not, by itself, comprise a complete IVHS solution. Rather, the TOC will provide a center in which other IVHS components can be controlled, monitored and integrated. Therefore, action should be taken now to set in motion the deployment of the needed sensors, field controllers, communications links and information services. This will ensure that maximum benefits are gained from the TOC, and ultimately from IVHS as a whole.

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